
THE B.C. ENERGY DEMAND FORECASTING AND PLANNING MODEL

STAFF PAPER



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**The British Columbia Energy Demand
Forecasting and Planning Model**

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1. OVERVIEW OF THE MODEL

1.1 Introduction

This paper presents the current version of the British Columbia Energy Demand Forecasting and Planning Model. This model is a detailed econometric model which can be used in the development of energy demand forecasts and related policy analyses in British Columbia. An initial version of the model was prepared during the spring and summer of 1982 through the cooperative efforts of Ministry staff, the Canadian Energy Research Institute and Dr. R.N. McRae of the University of Calgary. The current version of the model, reported herein, reflects the considerable refinements and extensions undertaken by Ministry staff during the fall of 1982 and winter of 1982/83.¹

A detailed 'top-down' approach has been used in modelling energy demand. In this approach, total energy is first modelled by sector and subsector (and region, where appropriate), and energy demands by fuel type are derived from corresponding market share equations. These detailed forecasts are aggregated to obtain total energy requirements by fuel type and region, and ultimately total provincial energy requirements.

The major categories of required exogenous variables are prices, economic growth and demographic activity. Detailed energy price and output price assumptions by sector are used to incorporate the effect of changes in real energy prices on energy demand, and the effects of economic activity levels are modelled

¹ Major contributions were made by G. Macauley, T. Bennett, J. Rana and W. Bell of the Forecast and Special Projects Branch. The Ministry gratefully acknowledges the invaluable assistance of the Canadian Energy Research Institute and Dr. R.N. McRae of the University of Calgary during the early stages of this ongoing project. In addition, the University of Victoria has provided an excellent computing facility which was compatible with our needs.

through sectoral economic growth rate assumptions. There are no feedbacks from energy demand onto prices or economic activity levels in the current version of the model. The equations and data base are controlled by a simulator which was developed by Dr. R.N. McRae.²

1.2 The Market Sectors Modelled

Energy demand is modelled by market sector. The main sectors include commercial, residential, transportation, industrial, and non-energy demand. Commercial and residential demand are each modelled separately for the Mainland and Vancouver Island.

The industrial sector consists of the manufacturing, mining, and other industrial subsectors. Manufacturing demand is disaggregated into seven subsectors; pulp and paper, wood products, primary metals, chemicals, non-metallic minerals, petroleum refining, and other manufacturing.

Rail, air, road and marine have all been modelled separately in the transportation sector. Non-energy consumption of energy products consists of separate demands for asphalt, lubes and greases, and petrochemical feedstocks.

² The simulator is based on that developed by the Bank of Canada for its RDX macroeconomic models. In addition, Dr. McRae developed a number of computer programs which allow the data base to be transformed into a format directly useable by the simulator with a minimum of effort. This development has greatly enhanced subsequent research efforts.

1.3 The Methodology

A flowchart of the model is provided in Figure 1.

The general methodology used in forecasting energy demands in the residential, commercial, and most of the manufacturing and industrial subsectors is the same. First, drawing upon neo-classical micro-economic theory, total energy equations for each subsector are developed by relating such demands to their major determinants: economic activity levels, energy and other prices and demographic variables. Second, market share equations are developed by relating the market share of each energy type to relative energy prices and other variables. Energy demands by fuel and sector are then derived by applying the market shares to the total energy estimates. The energy volumes are modelled in output petajoules, using the utilization efficiencies presented in Table 1.1.

Certain restrictions have been imposed on the estimated market share equations.³ Most important, these restrictions ensure that the shares sum to unity. In addition, economic theory suggests two sets of constraints for the coefficients of the price variables. First, the market shares of each fuel should remain unchanged if the prices of all fuels change by the same proportion. Second, the change in the market share of one fuel with respect to a given percentage change in the price of another fuel should be equal to the change in market share of the other fuel with respect to the same percentage change in the price of the first fuel.

³ All coefficients reported herein have been estimated using version 3.1.1 of SHAZAM residing at the University of Victoria.

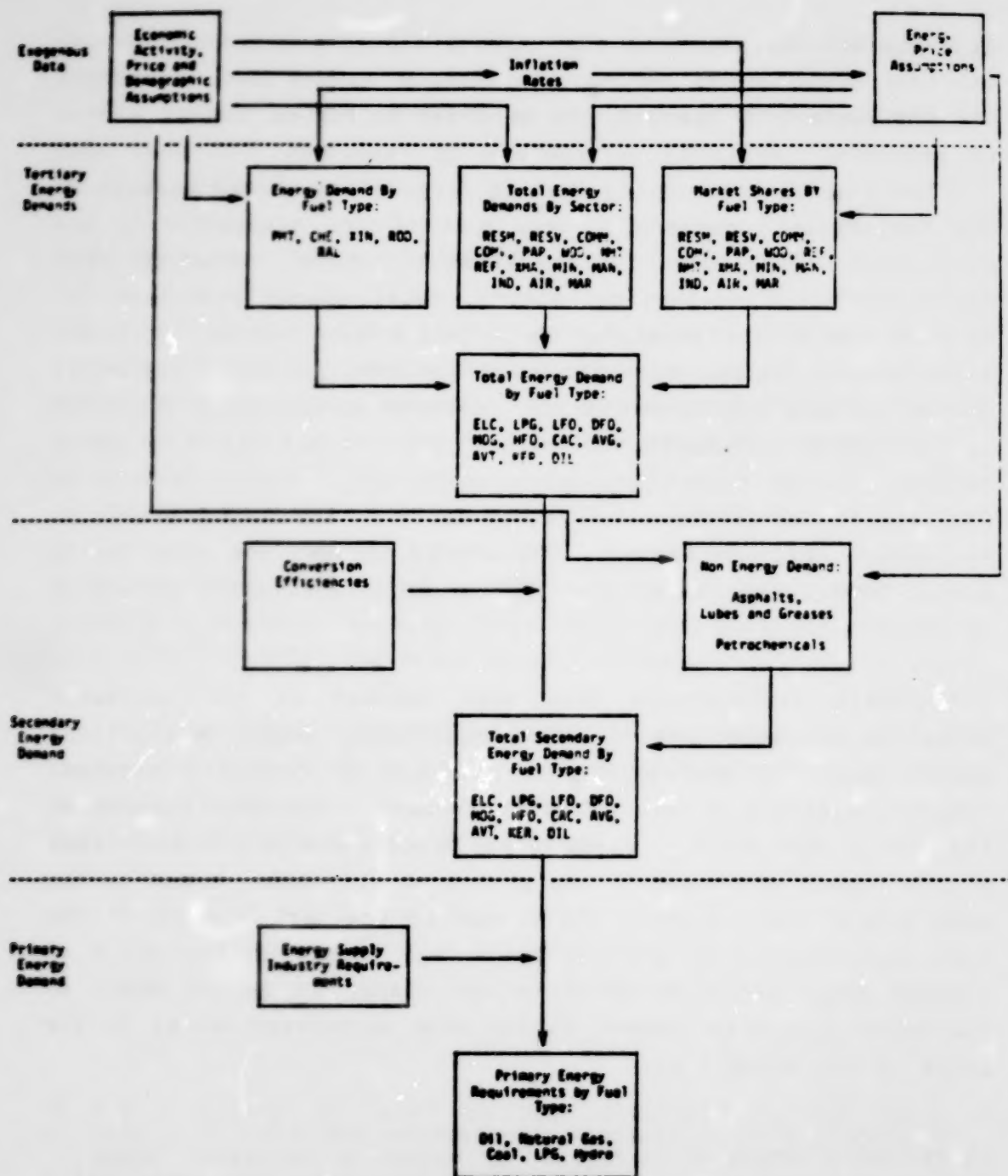


Figure 1: Flowchart of B.C. Energy Demand Model

TABLE 1.1
UTILIZATION EFFICIENCY FACTORS
(%)

	Residential	Commercial	Industrial	Transportation			
				Road	Rail	Air	Marine
Coal	50	65	87	-	8	-	8
LPG	65	78	85	-	-	-	-
Still Gas	-	-	85	-	-	-	-
Kerosene	65	82	82	-	55	-	55
Diesel Oil	23	23	26	-	23	-	15
Light Fuel Oil	65	82	82	23	82	-	10
Heavy Fuel Oil	80	80	87	-	80	-	10
Motor Gasoline	-	-	-	20	-	-	-
Aviation Gas	-	-	-	-	-	20	-
Aviation Turbofuel	-	-	-	-	-	30	-
Natural Gas	65	78	85	-	-	-	-
Electricity	100	100	100	-	-	-	-

SOURCE: Energy, Mines and Resources, Energy Demand Projections: A Total Energy Approach, Report ER-77-4, Ottawa, 1977 and National Energy Board.

For some subsectors, the total-energy/market-share approach either did not work or was inappropriate on a priori grounds. In those cases, sectoral energy demands by fuel type were modelled directly. This approach was used in modelling energy requirements in rail, road, primary metals, chemicals and non-energy use, (lubes and greases, asphalt and petrochemicals).

The estimated tertiary sectoral demands by energy type are converted from output requirements to input requirements or secondary demands by using the energy conversion efficiencies given in Table 1.1. These secondary demands provide estimates of the total fuels consumed by energy type.

The final stage in estimating total energy requirements is the conversion of secondary energy demands to primary requirements by adding energy used by the energy producing industries. Energy use in petroleum refining is explicitly incorporated into the petroleum refining submodel of the manufacturing subsector. The techniques for incorporating this into the model are outlined in section 7 of this report.

1.4 Adjustment Mechanisms

The adjustment of the consumption of energy to changes in energy (and other factor) prices is a process which is neither costless nor instantaneous. The ability of the consumer to respond depends upon the period of time over which behaviour is being observed. In the short run, relatively easy conservation measures may be undertaken, such as adding additional insulation or turning down the thermostat. In the longer term, however, the consumer will be undertaking investment decisions in which

energy, labour and capital are more flexible and each of these may substituted for one another. For example, a mill may rebuild a boiler or scrap a production process, or a residential consumer may triple-glaze his windows and install a high efficiency gas furnace.

The lag in the ability of the consumer results in the observation of both short and long run responses. Modellers have tended to estimate their equations in one of the three following specifications.³

$$1) \quad E = f(X, P)$$

$$2) \quad E = f(X, P, P(-1), \dots, P(-n))$$

$$3) \quad E = f(X, P, E(-1))$$

where E is the demand for energy, X is an array of explanatory variables, P is the price of energy and the bracketed negative terms denote lags upon the variable.

The first approach assumes that all adjustment takes place instantaneously and the estimated coefficients display an average of the long and short run price responses.

³ Recent empirical and theoretical literature has dealt with the issue of vintaging the capital stock wherein different ages (vintage) of capital stock embody different energy consumption technologies. This may be a line of future research for our model development.

The second approach recognizes that it is a history of prices on which consumers base their behaviour. Consumers may have decided to undertake changes in consumption patterns based on conditions from a number of years ago and have only recently been able to implement these changes. It is necessary to obtain a distribution of the lag structure of the relevant current and lagged prices.

The third approach centers around the inclusion of a lagged dependent variable and is derived in economic theory from an optimal stock adjustment mechanism. This approach is a useful method for imposing lag responses with a minimum loss of degrees of freedom, however, this approach imposes the same Koyck distributed lag upon all the independent variables. This lag structure may be somewhat restrictive as it is unlikely that consumers respond to all variables with the same delay (response to changes in output may be almost instantaneous while prices may impact with a long lag).

In the model, different analysts have modelled sectors with different approaches to incorporating lagged responses.

The first approach does not differentiate between long and short run impacts. The third approach has the difficulty with the assumption of a Koyck lag distribution for all independent variables and with the econometric problems associated with a lagged dependent variable. The second approach presents a dilemma to the modellers in that as the length of the lag on the price variable is increased, there is a corresponding reduction in the sample period for estimation. Where this approach was taken, the lag length was generally set at 3 years with linearly

declining weights on pragmatic grounds as the costs associated with reducing the sample size further did not allow a longer lag. The degrees of freedom did not allow experimentation with a more flexible lag distribution (Almon, Shiller).

1.5 Data Base

1) Energy Consumption Data

A) Residential Sector

Supply and Demand (DESD) and its successor the Quarterly Report on Energy Supply and Demand (QRES) form the data base for the residential sector. Estimates of fuel consumption for Vancouver Island and the Mainland were generated from the Statistics Canada data using information provided by B.C. Hydro for electricity and the Ministry of Industry and Small Business Development (MISBD) regarding regional refined petroleum product consumption.

B) Commercial Sector

Data was derived from the same sources as the residential sector.

C) Industrial Sector

1) Manufacturing

Purchased energy consumption data for the wood products, primary metals, petroleum refineries, chemicals, non-metallic minerals and "other" subsectors was obtained from the Statistics Canada publication Consumption of Purchased Fuel and Electricity (57-506 and 57-208).

The data for both purchased and non-purchased energy consumption by the pulp and paper subsector was derived from information provided by the Statistical Services of the Canadian Pulp and Paper Association (CPPA).

The data for the self-generation of hydroelectric power in the primary metals and chemicals subsectors was provided by the associated industries and the data regarding the consumption of "own-use" products (principally still gas) by petroleum refineries was taken from the DESD and QRESD publications.

ii) Mining

Data was taken from the Consumption of Purchased Fuel and Electricity publication.

iii) Other Industrial

This category is the statistical difference between the industrial total⁴ from the DESD and QRESD publications and the sum of the purchased fuel estimates from the Purchased Fuel publication for the manufacturing and mining subsectors and the estimates of self-generated hydroelectricity.

D) Transportation

Energy consumption was obtained from the Statistics Canada DESD and QRESD.

⁴ The consumption of refined petroleum products by industry in generating electricity has been added to the estimate of industrial consumption of refined petroleum products and the estimate of electricity consumption has been reduced accordingly.

2) Energy Price Data

This modelling effort has paid particular attention to the generation of time series for electricity, natural gas and refined petroleum product prices.

Regarding electricity prices, the Ministry examined the sectoral electricity consumption patterns in 1980/81 and determined a profile of electricity consumption for each sector (average load factor, applicable rate category, average consumption). This profile was applied to B.C. Hydro's electricity rate structures to generate the average (and marginal) price which a sector would have paid if its consumption profile had been constant.⁵ This methodology produces a consistent time series and allows the analyst the ability to examine the impact of changing both consumption profiles and rate structures.

Historical posted tank wagon prices for refined petroleum products were obtained from Lower Mainland petroleum refineries. Taxes (both federal and provincial) and dealer margins were added to generate effective posted prices to the consumer for aviation gasoline, aviation turbo fuel, diesel fuel oil (road and non-road), heavy fuel oil (industrial and marine), light fuel oil and motor gasoline (road and non-road). While posted prices may differ from the actual prices paid by the consumer (there may be some discounting on product prices), it is not generally possible to accurately produce the actual consumer prices and the posted prices should reflect the price movements.

⁵ It would be optimal to employ the historical consumption profiles on an annual basis, however, this information is not readily available.

3) Economic Activity Variables

The economic activity variables employed within the model were obtained from Statistics Canada, the B.C. Ministry of Industry and Small Business Development, and Ministry of Energy, Mines and Petroleum Resources (MEMPR) publications or generated from data series from the above data sources.

1.6 Outline of the Report

The various sectoral models are briefly summarized in sections 2 through 6 of this report.

Section 7 contains a discussion of the conversion from secondary to primary energy demands while the regional disaggregation incorporated into the model is discussed in Section 8. Section 9 provides a brief discussion of the model's properties under simulation, Section 10 discusses the incorporation of exogenous variables and Section 11 contains a discussion of the model's uses. Finally, Section 12 outlines areas of future work.

2. THE RESIDENTIAL SECTOR

Energy consumption in the residential sector reported by Statistics Canada includes fuels consumed in houses (single attached, single detached, row and mobile homes), apartments (excluding natural gas) and by farms. The Ministry has produced an estimate of natural gas consumption in apartments and transferred this volume from the commercial to the residential sector. The farm use of diesel fuel consumption is modelled within the residential sector, while the consumption of motor gasoline by farms has been included in the road transport sector.

Total energy and market share equations have been developed for the Mainland and Vancouver Island, separately. This disaggregation has been undertaken principally to distinguish Vancouver Island as a major region which does not have access to natural gas from the Mainland, which does. The separation has made the market share analysis more straightforward.

Total energy demand, in output joules (OTOT), has been modelled as a function of the number of households (HH), real personal disposable income per household (YDPIHH), the real price of energy¹ (PE) and a degree day (DD) variable to accommodate meteorological variations. Regional time series have been produced for each of these variables, with the exception of the disposable income term where the provincial average has been incorporated. The time required to respond to real energy price changes has been introduced into the equation through a distributed lag on the real energy price. It has been assumed that total energy demand is linearly homogeneous with respect to the number of households.

¹ The real price of energy is defined throughout this report as the weighted price of energy, in output joules, deflated by the B.C. Consumer Price Index.

The total energy equation for the Mainland was estimated as:

$$\begin{aligned}
 (2.1) \quad \text{Log}(\text{OTOT}/\text{HH}) = & - 17.040 + 0.3796 * \text{Log}(\text{YDPIHH}) \\
 & (9.3) \quad (4.8) \\
 & - 0.1192 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PE}(-i)) \\
 & (0.9) \\
 & + 1.1885 * \text{Log}(\text{DD}) \\
 & (5.7)
 \end{aligned}$$

R-Square (adjusted) = .786
 Standard Error of Estimate = .030
 Durbin-Watson = 1.83
 Estimation Period: 1964-1980

where $w(i)$ takes on the values 0.500, 0.333 and 0.167 for i equal to 0, 1 and 2.

The total energy equation for Vancouver Island was estimated as:

$$\begin{aligned}
 (2.2) \quad \text{Log}(\text{OTOT}/\text{HH}) = & - 18.203 + 0.2176 * \text{Log}(\text{YDPIHH}) \\
 & (7.9) \quad (1.6) \\
 & - 0.1383 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PE}(-i)) \\
 & (1.7) \\
 & + 1.2423 * \text{Log}(\text{DD}) \\
 & (5.0)
 \end{aligned}$$

R-Square (adjusted) = .741
 Standard Error of Estimate = .032
 Durbin-Watson = 1.92
 Estimation Period: 1964-1980

where variable definitions are the same as for the Mainland.

The total energy equations for both the Mainland and Vancouver Island fit the data well. The degree day and income coefficients have the correct sign, are statistically significant and reasonable. The coefficients on the price terms seem somewhat low and the coefficient for the Mainland is in fact statistically insignificant. These equations are generally quite good and will be retained until future experimentation supersedes them.

The market shares have been modelled as a function of relative energy prices and the ratio of the stock of multiple to total dwelling units (KHUSMULT/KHUSTOT). The housing stock variable has been introduced to reflect the fact that different fuels tend to be consumed in different housing structures. Apartments tend to consume electricity as their principal heating fuel, as apartments are usually renter-occupied and the owner/operator will generally select a heating system which can be individually metered and which has low capital costs.

The fuel prices used in equations (2.6) through (2.9) have the same imposed lag distribution as the price term in the total energy equation. Cross-equation restrictions have been placed upon the estimated parameters to ensure consistency with economic theory. For the set of equations for market shares (S_i)

$$S_i = a_i + \sum_{j=1}^3 b_{ij} * \text{Log} (P(j))$$

for fuel types 1, 2 and 3 (electricity, gas and oil respectively).

The following restrictions on the coefficients have been set:

$$(2.3) \quad \sum_{i=1}^3 a_i = 1$$

$$(2.4) \quad b_{ij} = b_{ji} \quad (i=j)$$

and

$$(2.5) \quad \sum_{i=1}^3 b_{ij} = 0$$

Conditions (2.3) and (2.5) ensure that market shares will sum to unity and condition (2.4), the symmetry condition, imposes the restriction that the impact of a change in the price of fuel i on fuel j should have the same impact as an equal change in the price of fuel j on fuel i . Condition (2.5) also ensures that market shares will remain unchanged if all prices rise by the same amount (homogeneity of degree zero in prices).

The share equations for the Mainland have been estimated as:

$$\begin{aligned}
 (2.6) \quad \text{SNGS} = & - 0.2595 - 0.1783 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{PNGS}(-1)) \\
 & \quad (0.7) \quad (1.3) \\
 & + 0.0398 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{PELC}(-1)) \\
 & \quad (0.4) \\
 & + 0.1384 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{POIL}(-1)) \\
 & \quad (4.2) \\
 & - 0.1016 \cdot \text{Log}(\text{KHUSMULT}/\text{KHUSTOT}) \\
 & \quad (0.5)
 \end{aligned}$$

R-Square (adjusted)	= .902
Standard Error of Estimate	= .008
Durbin-Watson	= 2.22

$$\begin{aligned}
 (2.7) \quad \text{SELC} = & 0.7030 + 0.0398 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{PNGS}(-1)) \\
 & \quad (2.5) \quad (0.4) \\
 & - 0.1745 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{PELC}(-1)) \\
 & \quad (1.8) \\
 & + 0.1346 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{POIL}(-1)) \\
 & \quad (4.5) \\
 & + 0.2184 \cdot \text{Log}(\text{KHMULT}/\text{KHUSTOT}) \\
 & \quad (1.4)
 \end{aligned}$$

R-Square (adjusted)	= .906
Standard Error of Estimate	= .010
Durbin-Watson	= 1.72

$$\begin{aligned}
 (2.8) \quad \text{SOIL} = & 0.4435 + 0.1385 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PNGS}(-1)) \\
 & + 0.1347 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PELC}(-1)) \\
 & - 0.2730 * \sum_{i=0}^2 w(i) * \text{Log}(\text{POIL}(-1)) \\
 & + 0.1168 * \text{Log}(\text{KHUSMULT}/\text{KHUSTOT})
 \end{aligned}$$

Estimation Period: 1969-1980

Where NGS signifies natural gas and SNGS is the share of natural gas to total energy in output joules. Correspondingly, ELC stands for electricity and oil is defined to be the aggregate of light fuel oil (LFO), heavy fuel oil (HFO), liquid petroleum gases (LPG), and coal and coke (CAC). The share equations for the Mainland fit the data well; the price coefficients have the "correct" signs and the own- (as well as two of four cross-) price coefficients are statistically significant.

The share equation for Vancouver Island appears as:

$$\begin{aligned}
 (2.9) \quad \text{SELC} = & \underset{(17.6)}{0.9481} - \underset{(8.8)}{0.3185} * ((\sum_{i=0}^2 w(i) * \text{Log}(\text{PELC}(-1)))) \\
 & - (\sum_{i=0}^2 w(i) * \text{Log}(\text{POIL}(-1))) \\
 & + 0.2019 * \text{Log}(\text{KHUSMULT}/\text{KHUSTOT}) \\
 & \quad (3.6)
 \end{aligned}$$

R-Square (adjusted) = .949
 Standard Error of Estimate = .018
 Durbin-Watson = 1.11
 Estimation Period: 1964-1980

The equation appears to fit the data well with the estimated coefficients being statistically significant and of correct a priori sign.

Diesel fuel oil (DFO) is consumed in the residential sector primarily by farming operations and diesel fuel consumption has been modelled solely as a function of output (as measured by GDP) in the agricultural sector. Incorporation of a price term into the specification was not successful.

$$(2.10) \quad \text{Log (DDFO)} = -4.557 + 1.108 * \text{Log (GDP)} \\ (4.1) \quad (5.0)$$

R-Square	= .630
Standard Error or Estimate	= .140
Durbin-Watson	= 0.86
Estimation Period:	1966-1980

While the equation does not fit the data extremely well, the coefficient on the agricultural output term is statistically significant and is very reasonable.

3. THE COMMERCIAL SECTOR

The commercial sector is composed of a very heterogenous group of economic activities and corresponding fuel consumption patterns. Table 3-1, below, presents the composition of the commercial sector by economic activity and energy consumption which existed in 1979.

Table 3-1
Composition of the Commercial Sector

	<u>Gross Domestic Product¹</u>		<u>Energy Consumption²</u>	
	<u>Millions of 1971 Dollars</u>	<u>Percent</u>	<u>Input Petajoules</u>	<u>Percent</u>
Public Admin.	912	10.1	16.3	18.4
Trans., Comm. and Storage	1704	89.9	53.0	74.9
Wholesale Trade	759			
Retail Trade	1072			
Fin., Ins. and Real Estate	1530			
Community, Bus. and Personal Services	3012			
Other			1.5	2.1
	8989		70.8	

¹ MISBD, British Columbia Economic Accounts 1961-1980

² MEMPR Energy Supply and Requirements Forecast, 1980 - 1995, April 1981. Tables 3.1A.

In its previous energy demand forecasts, the Ministry has attempted to disaggregate energy consumption within the commercial sector through extensive surveys of schools, hospitals, hotels, office buildings and other commercial establishments. The impacts of economic growth and conservation have then been applied to the base year data to obtain a final forecast of energy requirements for the commercial sector. While considerable information has been collected for recent years, there is an insufficient time series of data with which to estimate energy demand equations for components of the commercial sector. For the current version of the model, we have estimated a single total energy equation for Vancouver Island and the Mainland for the commercial sector in aggregate.

We will continue to undertake extensive market intelligence which will be melded with the model results in preparing our final forecast of energy requirements.

The modelling of the energy requirements of the commercial sector relies upon the data base generated from the Statistics Canada publications DESD and QRES. We have correspondingly defined the commercial sector to exclude agriculture³ and construction.⁴ In addition, utilities have been excluded from the definition of economic activity in the commercial sector as their energy requirements are generally included in the supply industries. The commercial sector includes the estimates of LFO consumption in the rail and marine subsectors and HFO in the rail subsector as it is assumed that these fuels are consumed in a commercial activity (offices, storage) rather than as a transport activity.

3 Included in the residential sector and other motor gasoline use.

4 Included in the "other industrial" category.

Estimates have been made of the consumption of natural gas consumed in apartments (generally reported as a "commercial sale") and this consumption has been shifted to the residential sector.

The commercial sector has been regionally disaggregated between Vancouver Island and the Mainland, as briefly discussed in section 1.5 above. Total energy and fuel market shares have been estimated for each of these regions.

In order to capture the lag which is required in adjusting total energy consumption (and market shares) to changes in total (and relative) energy prices, a lagged dependent variable has been introduced into the analysis. After much experimentation, a coefficient of 0.6 was imposed upon the lagged dependent variable, implying that 90 percent of the adjustment is achieved within 5 years.

Total energy (OTOT), measured in output joules, has been modelled as a function of real economic activity (GDP⁵), real energy prices (PE), degree days(DD), the lagged dependent variable, and dummy variables to net out erratic movements.

⁵ GDP was defined for each region as GDP for the commercial sector (excluding utilities) multiplied by the ratio of regional to total population.

For the Mainland, the total energy equation has been estimated as:

$$\begin{aligned}
 (3.1) \quad \text{Log}(\text{OTOT}) = & - 1.816 + 0.4302 * \text{Log}(\text{GDP}) \\
 & (1.7) \quad (11.2) \\
 & - 0.3743 * \text{Log}(\text{PE}) + 0.0107 * \text{GFD}(\text{Log}(\text{DD})) \\
 & (3.1) \quad (0.4) \\
 & - 0.1630 * \text{GFD}(\text{DMY63} + \text{DMY68}) \\
 & (5.5) \\
 & + 0.6 * \text{Log}(\text{OTOT}(-1))
 \end{aligned}$$

R-Square (adjusted) = .918
 Standard Error of Estimate = .047
 Durbin - Watson = 2.50
 Estimation Period: 1963 - 1980

where GFD (X) denotes the generalized first difference operator $X - (0.6 * X(-1))$. This operator has been applied to the degree days and dummy variables to allow each to have an instantaneous impact upon the energy requirements.⁶

⁶ Using the lag operator (L), equation (3.1) may be re-written in the following manner (ignoring the dummy term):

$$\begin{aligned}
 (1-.6L) \text{Log}(\text{OTOT}) = & a_1 + a_2 * \text{Log}(\text{GDP}) + a_3 * \text{Log}(\text{PE}) \\
 & + a_4 * (1-.6L) * \text{Log}(\text{DD})
 \end{aligned}$$

This equation may be transformed to the form:

$$\begin{aligned}
 \text{Log}(\text{OTOT}) = & a_1 * (1-.6L)^{-1} + a_2 * (1-.6L)^{-1} * \text{Log}(\text{GDP}) \\
 & + a_3 * (1-.6L)^{-1} * \text{Log}(\text{PE}) + a_4 * \text{Log}(\text{DD})
 \end{aligned}$$

where $(1-.6L)^{-1}$ is the Koyck distributed lag operator mentioned in section 1.4 above. The DD variable therefore has an instantaneous impact upon total energy.

The equation for Vancouver Island was estimated as:

$$\begin{aligned}
 (3.2) \quad \text{Log(OTOT)} = & - 3.3614 + 0.4969 * \text{Log(GDP)} \\
 & (2.5) \quad (8.4) \\
 & - 0.3814 * \text{Log(PE)} + 0.3180 * \text{GFD(Log(DD))} \\
 & (2.7) \quad (0.8) \\
 & - 0.1182 * \text{GFD (DMY63 + DMY68)} \\
 & (3.1) \\
 & + 0.6 * \text{Log(OTOT(-1))}
 \end{aligned}$$

R-Square (adjusted) = .868
 Standard Error of Estimate = .058
 Durbin - Watson = 2.33
 Estimation Period: 1963 - 1980

These equations seem to fit the data reasonably well and the coefficients for output and energy prices are both reasonable and statistically significant. The short (long) run price elasticity is 0.37 (0.94) for the Mainland and 0.38 (0.95) for Vancouver Island.

The fuels have been aggregated into 3 fuel types: electricity (ELC), natural gas (NGS) and oil (OIL) which is a composition of coal, diesel, heavy and light fuel oils and liquefied petroleum gases. These equations were estimated incorporating the appropriate cross-equation constraints outlined in the residential sector over the period from 1963 to 1980. A pipeline variable⁷ (KNGSPIPE) has been introduced into the

⁷ Defined as the number of kilometres of natural gas distribution pipe.

Mainland equation to explain the shift from oil and electricity to natural gas which was facilitated by the expansion of natural gas service rather than from a change in relative prices per se.

The system of equations for the Mainland were estimated as:

$$\begin{aligned}
 (3.3) \quad \text{SOIL} &= 1.4815 - 0.0560 * \text{Log}(\text{POIL}) + 0.0050 * \text{Log}(\text{PNGS}) \\
 &\quad (3.5) \quad (3.1) \quad (0.2) \\
 &\quad + 0.0509 * \text{Log}(\text{PELC}) - 0.1563 * \text{Log}(\text{KNGSPIPE}) \\
 &\quad (3.2) \quad (3.3) \\
 &\quad - 0.0741 * \text{GFD}(\text{DMY68}) + 0.6 * \text{SOIL}(-1) \\
 &\quad (5.3)
 \end{aligned}$$

R-Square (adjusted) = .971
 Standard Error of Estimate = .019
 Durbin - Watson = 2.93

$$\begin{aligned}
 (3.4) \quad \text{SELC} &= 0.2581 + 0.0509 * \text{Log}(\text{POIL}) + 0.0434 * \text{Log}(\text{PNGS}) \\
 &\quad (0.6) \quad (3.2) \quad (1.0) \\
 &\quad - 0.0944 * \text{Log}(\text{PELC}) - 0.0010 * \text{Log}(\text{KNGSPIPE}) \\
 &\quad (2.7) \quad (0.0) \\
 &\quad + 0.0278 * \text{GFD}(\text{DMY68}) + 0.6 * \text{SELC}(-1) \\
 &\quad (2.2)
 \end{aligned}$$

R-Square (adjusted) = .794
 Standard Error of Estimate = .019
 Durbin-Watson = 2.77

$$\begin{aligned}
 (3.5) \quad \text{SNGS} = & -1.3396 + 0.0050 * \text{Log}(\text{POIL}) - 0.0484 * \text{Log}(\text{PNGS}) \\
 & + 0.0435 * \text{Log}(\text{PELC}) + 0.1573 * \text{Log}(\text{KNGSPIPE}) \\
 & - 0.0463 * \text{GFD}(\text{DMY68}) + 0.6 * \text{SNGS}(-1)
 \end{aligned}$$

Estimation Period: 1963 - 1980

These estimates fit the data well (a standard error of less than two percentage points), all coefficients have the theoretically correct signs and the own- (and two of four cross-) price coefficients are statistically significant.

The single market share equation estimated for Vancouver Island appears as:

$$\begin{aligned}
 (3.6) \quad \text{SELC} = & 0.2773 - 0.1416 * \text{Log}(\text{PELC}/\text{POIL}) \\
 & (11.1) \quad (4.9) \\
 & + 0.0515 * \text{GFD}(\text{DMY68}) + 0.6 * \text{SELC}(-1) \\
 & (1.8)
 \end{aligned}$$

R-Square (adjusted) = .587
 Standard Error of Estimate = .033
 Durbin-Watson = 1.58
 Estimation Period: 1963 - 1980

While this equation does not fit as well as the system of equations for the Mainland, it remains a very respectable equation.

The complete system of total energy and market sharing equations for the commercial sector seem quite reasonable: elasticities are of reasonable magnitude; coefficients are of the correct sign and generally statistically significant; and the equations fit the data reasonably well.

4. THE INDUSTRIAL SECTOR

4.0 Introduction

The industrial sector in British Columbia is heavily concentrated in a small number of resource processing industries. Statistics Canada and the Ministry have estimated the distribution of energy consumption in 1979 as follows:

Table 4-1

	Purchased Fuels ¹		Total Energy ²	
	Input Petajoules	Percent	Input Petajoules	Percent
Manufacturing				
Pulp and Paper	79.4	42.3	235.7	55.7
Wood Products	23.2	12.4	51.9	12.3
Primary Metals	7.4	3.9	40.8	9.6
Petroleum Refining	6.2	3.3	19.6	4.6
Chemicals	9.2	4.9	10.8	2.6
Non-Metallics	14.2	7.6	16.2*	3.8
Other Manufacturing	10.8	5.8	10.4*	2.5
Mining	21.7	11.6	21.6	5.1
Other Industrial	15.6 ³	8.3	14.9	3.5
	187.5		423.0	

* Difference arises solely due to estimate of purchased fuels rather than self-generation.

¹ Statistics Canada, Consumption of Purchased Fuel and Electricity, Publication No. 57-506 (1962-1974) and 57-208 (1975-1979).

² MEMPR, op. cit., (1981) Tables 4.2, 4.24, 4.27, 4.29, 4.31, 4.38, 4.63, 4.77 and 4.87. (excludes construction)

³ Logging (Purchased Fuel) plus construction (QRESD).

The industrial sector has been disaggregated into the above noted categories (7 subsectors of the manufacturing sector, the mining sector and the "other industrial" sector) and each of these has been modelled separately as a function of output, real factor prices (energy, capital and labour) and other industry specific explanatory variables. This chapter will initially examine the general philosophy underlying the estimation of the industrial sector equations, and will be followed by the empirical results for each of the 9 subsectors identified above.

4.1 Methodology

4.1.1 Equation Specification

Equations have been estimated for total energy and fuel shares for each of the subsectors identified above. Total energy and fuel market shares have been defined in output joules, as have energy prices.

In modelling both total energy and market shares, a consistent equation specification formed the foundation for subsequent analysis.⁴ Energy is modelled as a factor of production within the context of the neo-classical "theory of the firm". The demand for energy is a function of industrial output and the prices of the factors of production (capital, labour and energy). Substitution between factors of production occurs as the firm attempts to minimize its costs (subject to constraints) given the prices of each factor of production. The general specification employed appears as:

⁴ Experimentation included the "cost share" approach which, although well grounded in theory, did not produce superior estimates.

$$\begin{aligned}\text{Log}(\text{OTOT}) &= a_1 + a_2 * \text{Log}(\text{OUTPUT}) \\ &+ a_3 * \text{Log}(\text{PE})\end{aligned}$$

where OUTPUT denotes a measure of industrial output and PE denotes the real price of energy. The CPI has been introduced as a proxy for the general price level including all factors of production (labour, capital, energy and material inputs) and the ratio of energy prices to the CPI is employed as a proxy for the price of energy relative to all other factors of production.

Some experimentation was undertaken to incorporate lagged responses to energy (and other) prices. The lagged dependent variable was introduced into a number of subsectors with its coefficient either estimated through regression analysis or specified exogenously by the analyst. Alternatively, the lagged response has been estimated by modelling energy consumption as a function of a distribution of lagged real energy (and other) prices. In general, the second approach to incorporating lagged price responses has been undertaken. Where experimentation with lagged responses did not prove fruitful, instantaneous adjustment equations have been employed with the result that the coefficients can be interpreted as an average of long and short run responses.

The energy types have generally been aggregated into three fuels; electricity (ELC), natural gas (NGS), and oil (OIL), where oil has been defined variously to include coal, diesel fuel oil (DFO), heavy fuel oil (HFO), light fuel oil (LFO) and liquefied petroleum gases (LPG). The share of total energy which each fuel represents has been modelled in the following form:

$$S_i = a_i + \sum_{j=1}^3 b_{ij} * \text{Log}(\text{PE}(j))$$

where the restrictions on the a_i and b_{ij} are the same as those discussed in the residential sector.

Where there are attributes of a subsector which suggest the inclusion of an additional variable to explain the pattern in market share adjustment⁵, the necessary variable has been included.

Electricity presents a problem to the modeller as it is often a "specialized" fuel used in applications for which it has no substitute. For this reason it is treated as a separate fuel in the primary metals and chemical industries. Within the remaining subsectors electricity was treated in a market sharing framework as there is generally at least some limited substitution potential. Where regression analysis yielded estimates which were either statistically insignificant or of the "wrong" sign for the price of electricity, its share was essentially exogenized (the impact of a change in the price of electricity is felt solely through the total energy equation).

⁵ Such as the importance of the growth in the Interior lumber industry relative to the Coast in the wood products industry (equations 4.2.2.2 to 4.2.2.4) or the growth of the coal industry in the mining sector (equations 4.3.2 to 4.3.4). In each of these cases, the event has led to a significant increase in the consumption of natural gas relative to other fuels.

4.2 MANUFACTURING

4.2.1 Pulp and Paper

As noted in Table 4-1, above, pulp and paper accounts for approximately 42 percent of purchased and 56 percent of total energy consumption in the industrial sector. In 1979, there were 25 mills operating within the province producing newsprint, kraft pulp, mechanical pulp and a wide range of paper products.

A major feature of the pulp and paper subsector is the volume of energy consumed within the mills which is produced in the production process or from "waste" materials. Pulping liquor is a chemical solution containing chemicals used in the pulping process (caustic soda, chlorine and sodium chlorate) and fibrous materials derived from the chips during the kraft pulping process. This solution is burned in a mill's "recovery boiler" to recover the chemical contents and in the process generates heat which is used in the production process. Hog fuel is "waste" product generated from the production of wood chips at the mill site or delivered to the mill from sawmills and other forestry operations.

There are two alternate sources of data regarding fuel consumption by the pulp and paper mills within British Columbia: the Statistics Canada publication, Consumption of Purchased Fuel and Electricity, and the Canadian Pulp and Paper Association (CPPA).

The Statistics Canada publication does not contain estimates of hog fuel or pulping liquors consumed by the pulp and paper sector. To use this data source for modelling purposes would require the construction of time series for each of these variables. Meaningful times series for each of these fuel types could not be produced for years other than 1972 and 1977 through 1981 and to produce time series for other years on an ad hoc basis would invalidate the estimates of the relationship between fuel consumption, prices and production.

The CPPA data is rich in detail as it contains the fuel consumption patterns (including self-generated energy) for each of the mills within the province. This data, however, exists only for the years 1972 and 1977 through 1981.

It was determined that the most effective way of utilizing the CPPA data for modelling purposes would be to estimate pooled cross-section/time-series equations. Given the heterogeneity of the production processes, the total sample was divided into five groups:

- (1) South Coast integrated kraft/newsprint mills
- (2) South Coast kraft mills
- (3) Lower Mainland paper mills
- (4) Interior and North Coast mills
- (5) Ocean Falls⁶

⁶ Ocean Falls has been identified as a separate mill group as it ceased operation in 1979, was small, and had very different fuel consumption patterns (large volumes of heavy fuel oil, no purchased electricity, small volumes of hog fuel) than the other mill groups. To include this mill in one of the other groups would have severely influenced the econometric results.

As a proportion of total energy consumption, in output joules, regions 1 through 4 accounted for 31.3, 20.9, 2.2 and 45.6 percent, respectively in 1980.

This grouping seems very natural as each group has different production processes⁷ and groups (1) and (2) do not have access to natural gas. This identification will aid in producing regional energy forecasts and in forecasting the market shares of natural gas and heavy fuel oil (prices will not affect the consumption of natural gas in a region which has no access to natural gas).

Equation Specification

Total energy consumption (including pulping liquors and hog fuel), in output joules, has been modelled for regions 1, 2, 3 and 4 as a function of production and real energy prices. In an attempt to capture the lagged adjustment mechanism, a distributed lag on the real price term was imposed in the regression analysis.

For each region, the total energy equation was estimated using the mill specific data in a cross-section/time-series setting. The estimated parameter for the price term (and in the case of region 1, the ratio of newsprint to total production) has the property of a long run elasticity as it is estimated over mills with somewhat different vintages of capital structure.

⁷ While the South Coast and Interior kraft mills have a similar production process, the Interior mills tended to be much newer and may have significantly more efficient production techniques.

An aggregate equation, incorporating the estimated parameters from the cross-section/time-series equations, was re-estimated over the years 1977 through 1980, to obtain a constant term for the aggregate equation.⁸ The total energy results reported below will display first the cross-section/time-series results, followed by the estimated constant term for the aggregate equation.

South Coast Integrated Kraft/Newsprint Mills

$$\begin{aligned}
 (4.2.1.1) \quad \text{Log}(\text{OTOT}) &= \text{Log}(\text{XOUT}) - 10.673 \\
 &\quad (520.7) \\
 &+ 0.6105 * \text{Log}(\text{XNPT}/\text{XOUT}) \\
 &\quad (3.3) \\
 &- 0.0594 * \sum_{i=0}^4 w(i) * \text{Log}(\text{PE}(-i)) \\
 &\quad (1.7) \\
 &+ \text{Mill Specific Dummies}
 \end{aligned}$$

R-Squared (adjusted)	= .837
Standard Error of Estimate	= .033
Number of Observations	= 28.0

⁸ In algebraic form, the cross-section/time-series equations were estimated as:

$$\begin{aligned}
 \text{Log}(\text{OTOT}_{ij}) &= a_i + \text{Log}(\text{OUTPUT}_{ij}) \\
 &+ B_1 * \text{Log}(\text{Price}_{ij})
 \end{aligned}$$

where the i subscript refers to the mill and the j subscript refers to time. The consumption, output and price data was aggregated to the regional level and the coefficient A_1 was estimated from the equation

$$\begin{aligned}
 \text{Log}(\text{OTOT})_j &= A_1 + \text{Log}(\text{OUTPUT})_j \\
 &+ B_1 * \text{Log}(\text{Price})_j
 \end{aligned}$$

It is this aggregated equation which is incorporated in the model.

XOUT denotes total production, XNPT denotes the production of newsprint⁹ and $w(i)$ represents a lag distribution on the price term which is approximately a truncated inverted-V distribution having weights of 0.23, 0.32, 0.23, 0.15 and 0.07. The constant term for the aggregate equation has been estimated as:

$$(4.2.1.2) \quad \text{Constant} = -10.374 \\ (929.9)$$

$$\text{Standard Error of Estimate} = .022$$

South Coast Kraft Mills

$$(4.1.2.3) \quad \text{Log(OTOT)} = \text{Log(XOUT)} - 9.9794 \\ (407.7) \\ - 0.11957 \sum_{i=0}^4 w(i) * \text{Log(PE(-i))} \\ (2.5) \\ + \text{Mill Specific Dummies}$$

$$\begin{aligned} \text{R-Square (adjusted)} &= .949 \\ \text{Standard Error of Estimate} &= .042 \\ \text{Number of Observations} &= 25.0 \end{aligned}$$

Variable definitions are the same as above, and the constant term has been estimated as:

$$(4.1.2.4) \quad \text{Constant} = -10.314 \\ (573.5)$$

$$\text{Standard Error of Estimate} = .036$$

⁹ The ratio of newsprint to total production has been incorporated to reflect the fact that a tonne of newsprint requires more energy than a tonne of final kraft production. Newsprint requires energy in the production of kraft as an intermediate product as well as energy in converting kraft (and other) pulp to finished newsprint.

Lower Mainland Paper Mills

$$\begin{aligned}
 (4.2.1.5) \quad \text{Log(OTOT)} &= \text{Log(XOUT)} - 10.849 \\
 &\quad (309.0) \\
 &- .2393 \quad * \sum_{i=0}^4 w(i) * \text{Log(PE(-1))} \\
 &\quad (2.4) \\
 &+ \text{Mill Specific Dummies} \\
 \text{R-Square (adjusted)} &= .994 \\
 \text{Standard Error of Estimate} &= .046 \\
 \text{Number of Observations} &= 15.0
 \end{aligned}$$

Variable definitions are the same as above, and the constant term has been estimated as:

$$\begin{aligned}
 (4.2.1.6) \quad \text{Constant} &= -11.221 \\
 &\quad (828.6) \\
 \text{Standard Error of Estimate} &= .027
 \end{aligned}$$

Interior Kraft Mills

$$\begin{aligned}
 (4.2.1.7) \quad \text{Log(OTOT)} &= \text{Log(XOUT)} - 10.274 \\
 &\quad (272.8) \\
 &- 0.1026 \quad * \sum_{i=0}^4 w(i) * \text{Log(PE(-1))} \\
 &\quad (2.3) \\
 &+ \text{Mill Specific Dummies} \\
 \text{R-Square (adjusted)} &= .989 \\
 \text{Standard Error of Estimate} &= .053 \\
 \text{Number of Observations} &= 52
 \end{aligned}$$

Variable definitions are the same as above, and the constant term has been estimated as:

$$\begin{aligned}
 (4.1.2.9) \quad \text{Constant} &= -10.513 \\
 &\quad (499.8) \\
 \text{Standard Error of Estimate} &= .042
 \end{aligned}$$

Equations 4.2.1.1 through 4.2.1.8 seem to fit the data well and have reasonable estimated coefficients. Region 3 has a substantially higher price coefficient than the other regions because it purchases a significantly higher portion of its energy requirements than do other mill groups.

While the modelling of total energy consumption using econometric methods provides meaningful results, the interfuel substitution is not as amenable to these methods. Those features of interfuel substitution which are of significance include the following:

- (1) Kraft mills produce pulping liquors as a function of their kraft process and will not reduce the generation of steam from pulping liquors as a function of other energy prices. The production of pulping liquors may be reduced as the value of the fibre content increases and firms turn to mechanical (rather than chemical) processes which have a higher recovery of input fibre.
- (2) Electricity and fossil (and hog) fuels are substitutes in as much as the mills are able to "cogenerate" electricity by passing high pressure steam through a generator. The initiative to build additional cogeneration facilities depends upon the mill's steam flows, the pricing structure of electricity, the rate of return on the project (relative to other investments) and often relies upon piggy-backing on the construction of a new hog fuel boiler.
- (3) Hog fuel availability must be defined in a regional perspective as transport costs currently prohibit the shipment of surplus hog fuel over large distances. Within a region, there may be an effective constraint upon the amount of hog fuel available to the pulp and paper mills.

- (4) The regions have been selected such that three regions (1, 2 and 5) do not have access to natural gas and use heavy fuel oil as their principal fossil fuel, while two regions (3 and 4) consume natural gas as their principal fossil fuel.

The determination of fuel market share will require essentially four different analyses:

- (1) Market intelligence through discussions with the industry to determine substitution potential and likely developments.
- (2) Examination of the economic potential for additional hog fuel and cogeneration facilities. This work will follow the analytical work set forward by Helliwell, Cox and Margolick.
- (3) Running the mill-specific engineering model, developed by the Ministry, to analyze the market intelligence and the possible hog fuel and cogeneration potential to examine requirements within the mill. This is of particular importance in analyzing the requirements of the power boilers, recovery boilers and lime kilns separately (certain types of fuels may be used in each) and to ensure that the forecast is in fact feasible (i.e., steam flows balance).
- (4) Examination of the availability of fuels (principally hog fuel) to the mills. Where a constraint is in fact met, an increase in the consumption of fossil fuels (and an associated change in the total price of energy) will be required.

4.2.2 Wood Products

The wood products subsector in British Columbia is comprised of producers of lumber, plywood, particleboard, shakes and shingles. While the producers of the four latter products are not insignificant, the Ministry has estimated that lumber production accounted for 80 percent of purchased energy and 79 percent of total energy consumption, measured in input joules, in 1979.¹⁰ Consequently, emphasis has been placed upon the sawmill component of the industry in explaining both total energy and fuel shares.

One major feature of the sawmill industry in B.C. has been the shift in the importance of the Interior operations relative to the Coastal operations. From 1965 to 1981, the Interior's share of total provincial lumber production has increased from 48 to 67 percent. This shift is of particular importance in modelling energy requirements as the Interior mills kiln dry a considerably higher proportion of its production than do the Coast mills (leading to greater energy intensity) and consume major volumes of natural gas in lumber kilns (leading to an increased market share for natural gas). The modelling work has attempted to incorporate this attribute of the industry.

While the wood products industry consumes large volumes of self-generated hog fuel, the current analysis deals only with purchased energy sources as the industry does not prepare comprehensive statistics regarding hog fuel consumption. The impact of hog fuel upon purchased fuel consumption has been dealt with somewhat imperfectly by the inclusion of variables reflecting the price of capital and labour. The equation is a

¹⁰ MEMPR, op. cit., (1981) Tables 4.27, 4.29 and 4.31.

reduced form of a demand for total energy and a purchased/hog fuel sharing equation where the price of energy is the price associated with purchased fuels and the other factor prices are associated with the incremental cost of burning hog fuel (handling, boilers.)

Total energy consumption, measured in output joules, has been modelled as a function of lumber production, the real prices of capital, labour and energy, and a dummy variable to allow for the impact of strike activity in 1975. The regional variation in energy consumption, mentioned above, has been incorporated through the output variable LUMVAR, which is equal to:

$$1.0 \times \text{QLUM (Coast)} + 4.7 \times \text{QLUM (Interior)}$$

where QLUM (Coast) and QLUM (Interior) denote the production of sawn lumber on the Coast and in the Interior, respectively, and the coefficient 4.7 has been based on energy consumption in 1979.¹¹ The estimated equation appears as:

¹¹ The coefficient 4.7 is equal to:

$$\frac{\text{DNCS/QLUM(Interior)}}{(\text{DHFO} + \text{DLFO} + \text{DLPG})/\text{QLUM(Coast)}}$$

where the energy terms are presented in output joules in the year 1979. This variable assumes that all HFO, LFO and LPG's are consumed on the Coast while all natural gas is consumed in the Interior. Some natural gas is consumed in the Lower Mainland and the North Coast, but this volume is relatively small.

$$\begin{aligned}
 (4.2.2.1) \quad \text{Log(OTOT)} = & -9.445 + 0.9763 * \text{Log(LUMVAR)} \\
 & \quad (7.4) \quad (5.2) \\
 & - 0.6881 * \text{Log(PE)} \\
 & \quad (6.6) \\
 & + 1.0804 * \text{Log(PLAB)} \\
 & \quad (3.5) \\
 & + 0.3466 * \text{Log(PCAP)} \\
 & \quad (0.7) \\
 & + 0.0997 * \text{DMY75} \\
 & \quad (1.6)
 \end{aligned}$$

R-Square (adjusted) = .994
 Standard Error of Estimate = .036
 Durbin-Watson = 2.13
 Estimation Period: 1966 - 1979

The fuel market shares, in output joules, have been estimated as a function of real energy prices and the ratio of Interior lumber production to the provincial total. Once more, a dummy variable has been included to allow for the deviations attributed to the strike in 1975. Coal, LPG's and diesel, light and heavy fuel oils have been collapsed into a single energy type (OIL) with an appropriately defined price term.

The three fuel system of equations has been estimated as:

$$\begin{aligned}
 (4.2.2.2) \quad \text{SOIL} = & 0.4278 - 0.2347 * \text{Log(POIL)} + 0.2357 * \text{Log(PNGS)} \\
 & \quad (7.1) \quad (9.0) \quad (9.0) \\
 & - 0.0154 * \frac{\text{LogQLUM (Interior)}}{\text{QLUM (B.C.)}} \\
 & \quad (0.3) \\
 & + 0.0515 * \text{DMY 75} \\
 & \quad (4.0)
 \end{aligned}$$

R-Square (adjusted) = .790
 Standard Error of Estimate = .022
 Durbin-Watson = 1.78

$$\begin{aligned}
 (4.2.2.3) \quad \text{SNGS} = & \quad 0.3247 + 0.2347 * \text{Log}(\text{POIL}) \\
 & \quad (4.9) \quad (9.0) \\
 & - 0.2347 * \text{Log}(\text{PNGS}) \\
 & + 0.2950 * \frac{\text{LogQLUM}(\text{Interior})}{\text{QLUM}(\text{B.C.})} - 0.1186 * \text{DMY75} \\
 & \quad (3.9) \quad (5.2)
 \end{aligned}$$

R-Square (adjusted) = .797
 Standard Error of Estimates = .028
 Durbin-Watson = 1.72

$$\begin{aligned}
 (4.2.2.4) \quad \text{SELC} = & \quad 0.2475 - 0.2796 * \frac{\text{LogQLUM}(\text{Interior})}{\text{QLUM}(\text{B.C.})} \\
 & + 0.06708 * \text{DMY75}
 \end{aligned}$$

Estimation Period: 1968 - 1979

The own- and cross- price coefficients on electricity have been restricted to zero in light of the lack of substitutability between electricity and other fuels, and the lack of acceptable empirical results.

Equations (4.2.3.1) through (4.2.3.4) fit the data very well and provide very reasonable estimates of energy price (total, own- and cross-) and output elasticities.

4.2.3 Primary Metals

The primary metals subsector in British Columbia is dominated by two firms, Alcan and Cominco. These two firms generate major volumes of hydroelectricity which are consumed in the production of aluminum (Alcan), lead/zinc (Cominco) and fertilizers/chemicals (Cominco). In addition, Cominco consumes a significant volume of natural gas in its metal furnaces. In total, these two firms consume significantly more than 90 percent of the total energy requirements of the primary metals subsector.¹²

This subsector presents particularly difficult problems to the modeller as the major source of energy is self-generated and does not have a price associated with the per unit consumption.¹³ The opportunity cost for electricity is the appropriate price associated with this consumption as it represents the value of the fuel which the industry is foregoing in revenues by consuming rather than selling the power. As a proxy for the opportunity cost, the analysts employed the average unit cost which B.C. Hydro would have charged a large primary metals facility for electricity.¹⁴

¹² Coal and Coke have not been included in the analysis as these fuels are used principally as a reduction agent in the process rather than as an energy source.

¹³ Alcan and Cominco do pay provincial water rental fees, however, these rates are relatively low and of little significance in determining electricity consumption.

¹⁴ Alternatively, one could examine the capital and cost structure for each operation and produce an estimate of the imputed cost of electricity. This (very major) exercise has not been undertaken.

Given the nature of the industry, separate equations were estimated for each of the fuel types ELC, NGS and OIL, with the major explanatory variables being GDP in the primary metals subsector and the real price of energy.

The regression results for electricity were somewhat disappointing,¹⁵ though not unexpected. The measure of GDP is an inadequate output measure as it does not incorporate the very different electricity consumption patterns associated with its two major components (aluminum, lead/zinc). It is also uncertain whether the proxy for the opportunity cost of electricity is meaningful for Alcan and Cominco and consequently electricity requirements will be forecast exogenously in the current version of the model. The forecast will rely upon discussions with Alcan, Cominco and other producers regarding their production and energy consumption outlooks.

¹⁵ The best equation was estimated as:

$$\begin{aligned} \text{Log}(\text{DELC} + \text{ZELC}) &= 0.1625 + 0.6510 * \text{Log}(\text{GDP}) \\ &\quad (0.2) \quad (3.7) \\ &- 0.1377 * \text{Log}(\text{PELC}) \\ &\quad (1.4) \end{aligned}$$

R-Square (adjusted) = .464
 Standard Error of Estimate = .078
 Durbin-Watson = 1.75
 Sample Period: 1963 - 1979

where the mnemonic ZELC denotes the self-generation of electricity. The fit on this equation is rather low and the coefficient on output is low.

The natural gas equation did not provide very favourable results¹⁶ and suffers from not being linked directly to output of the Cominco operations. The natural gas requirements will likewise be forecast exogenously.

The quantity of fuels included in the OIL category is relatively small (less than 1 petajoule of input fuels) and an econometric equation, which links demand to lead and zinc production and real price of RPP's, has been maintained for forecasting this quantity. The equation appears as:

$$(4.2.3.1) \quad \text{Log(OIL)} = \begin{matrix} -6.4269 & + & 1.0643 & * & \text{Log(MINQPBZN)} \\ (2.4) & & (2.5) & & \end{matrix} \\ - \begin{matrix} 0.70175 & * & \sum_{i=0}^2 w(i) & * & \text{Log(POIL(-1))} \\ (1.8) & & & & \end{matrix}$$

R-Square (adjusted) = 0.61
 Standard Error of Estimate = 0.22
 Durbin-Watson = 0.88
 Estimation Period: 1964 - 1979

Where the distributed lag operator takes on the value of 0.5, 0.333, and 0.167 for i equal to 0, 1 and 2.

This equation does not fit the data well either, however its magnitude is very small and the volume is not "important" enough to spend the time undertaking extensive market intelligence and exogenously forecast.

¹⁶ The best equation was estimated as:

$$\text{Log(DNGS)} = \begin{matrix} 0.0962 & + & 2.1934 & * & \text{Log(PCAP)} \\ (0.7) & & (4.5) & & \end{matrix} \\ - \begin{matrix} 0.7021 & * & \text{Log(PNGS)} & + & 0.2065 & * & \text{Log(DNGS(-1))} \\ (3.1) & & & & (1.1) & & \end{matrix}$$

R-Square (adjusted) = .971
 Standard Error of Estimate = .091
 Durbin-Watson = 1.95
 Estimation Period: 1963 - 1979

The equation does not fit very well (a 9.1 percent standard error), the coefficient on the price of capital is "too large" and the equation does not include an output variable. A major problem with this equation may originate with the reporting of data to Statistics Canada and the subsequent compilation.

4.2.4 Petroleum Refining

There are currently seven petroleum refineries in British Columbia supplying approximately 88 percent of the province's total refined petroleum product consumption in 1979. Where products can not be produced within the province (through an incorrect production slate or refinery capacity) inter-regional transfers of product occur.

Refineries consume natural gas, electricity, and fuels produced during the refining process (still gas, heavy fuel oil, petroleum coke and a small amount of other products). As the value of these "own-use" fuels rises, the refineries will tend to replace them with less expensive fuels.

Total energy consumption by petroleum refineries has been modelled as a function of an index of production and the real price of energy. The index of production is the sum of the energy contents of total refined petroleum production (excluding heavy fuel oil and petroleum coke). The price of the own-use (OIL) fuels has been defined as the weighted price associated with the non- still gas components of own- use. The total energy equation has been estimated as:

$$\begin{aligned}
 (4.2.4.1) \quad \text{Log(OTOT)} = & - \underset{(6.3)}{3.1916} + \underset{(11.8)}{1.1195} * \text{Log(XOUT)} \\
 & - \underset{(2.9)}{0.21915} * \sum_{i=0}^2 w(i) * \text{Log(PE(-i))}
 \end{aligned}$$

R-Square (adjusted)	= .940
Standard Error of Estimate	= .051
Durbin-Watson	= 1.63
Estimation Period:	1965 - 1979

where the distributed lag operator $w(i)$ takes on the value of 0.5, 0.333 and 0.167 for i equal to 0, 1 and 2. This equation fits the data reasonably well and has output and price coefficients which are statistically significant and of a reasonable magnitude.

The market shares for natural gas and oil were modelled as a function of a distributed lag on real energy prices. The share of electricity (SELC) has remained relatively constant over time at approximately five percent and will be forecast exogenously. The share equations have been modelled as:

$$\begin{aligned}
 (4.2.4.2) \quad \text{SNGS} = & (1 - \text{SELC}) * (-0.1967) \\
 & (3.8) \\
 & - 0.3527 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PNGS}(-i)) \\
 & (6.7) \\
 & + 0.3527 * \sum_{i=0}^2 w(i) * \text{Log}(\text{POIL}(-i)) \\
 & (6.7)
 \end{aligned}$$

R-Square (adjusted)	= .760
Standard Error of Estimate	= .040
Durbin-Watson	= 1.09
Estimation Period:	1965-1979

$$(4.2.4.3) \quad \text{SOIL} = 1 - (\text{SELC} + \text{SNGS})$$

The production of refined petroleum products which drives equation (4.2.4.1) will be forecast by adding together final demand, products consumed by utilities in generating electricity, net inventory changes, net interproduct transfers, net exports and losses. If the refinery capacity (under normal operation) is not sufficient to meet this demand, it will be assumed that inter-regional/international transfers will meet the difference.

4.2.5 Chemicals

The chemicals subsector in British Columbia produces principally bleaching agents for the pulp and paper subsector, resins for the wood products subsector and fertilizers. In this subsector, the major portion of energy is consumed as a "material input" rather than as an energy source¹⁷ and as such it is appropriate to model each fuel type separately.

It is uncertain where the energy requirements associated with the manufacture of fertilizers are accounted for. Cominco produces chemicals at its Kimberley and Trail operations to reduce by-product gases to an environmentally acceptable level. The electricity consumed is provided from Cominco's own generating facilities and it is unclear whether the natural gas requirements are included in the primary metals or chemicals subsector. We assume here that these requirements are included in the primary metals sector and are forecast exogenously.

Most electricity consumption in the chemicals subsector is attributable to the production of bleaching agents (caustic soda, chlorine and sodium chlorate) which are consumed in the production of kraft pulp. While domestic production of bleaching agents need not vary exactly with pulp and paper

¹⁷ Arguments have been made by Chemical producers that electricity used in manufacturing bleaching agents is a material input and that their final product is, to a major extent, embodied electricity.

production¹⁸, the estimated equation for electricity consumption takes GDP in the pulp and paper sector as its sole explanatory variable. The equation appears as:

$$(4.2.5.1) \quad \text{Log}(\text{DELC}) = - 7.0793 + 1.4520 * \text{Log}(\text{GDPPAP})$$

(2.1) (2.6)

R-Square (adjusted)	= .456
Standard Error of Estimate	= .140
Durbin-Watson	= 1.51
Estimation Period: 1972 -1979	

The statistical fit of this equation is not particularly good and the coefficient on the output term may be somewhat high.

Natural gas consumption occurs in the production of bleaching agents, resins (phenolformaldehyde, ureaformaldehyde) and miscellaneous chemicals¹⁹. Natural gas consumption has been estimated solely as a function of GDP in the wood industry.

¹⁸ There may be: 1) imports of bleaching agents, 2) a shift in the production of pulp (kraft, mechanical) or 3) a shift in production from pulp to paper final products.

¹⁹ MEMPR (1981) has estimated on Table 4-203, that in 1979 0.80 pj of natural gas was consumed by identified resin producers, 1.17 pj by identified bleaching agent producers and 1.61 pj by other unidentified producers.

$$(4.2.5.2) \quad \text{Log(DNGS)} = - \underset{(7.3)}{5.4283} + \underset{(8.3)}{1.0089} * \text{Log(GDPWOD)}$$

R-Square (adjusted) = .800
 Standard Error of Estimate = .100
 Durbin-Watson = 1.70
 Estimation Period: 1963 - 1979

The volume of other fuels incorporated into the OIL variable are relatively small. The equation for oil has been estimated as a function of GDP in the wood and pulp and paper industries and a distributed lag on the real price of RPP's. The resulting equation appears as:

$$(4.2.5.3) \quad \text{Log(OOIL)} = - \underset{(3.6)}{7.0085} + \underset{(3.2)}{0.9469} * \text{Log(GDPWOD + GDPPAP)} \\ - \underset{(4.4)}{0.9148} * \sum_{i=0}^2 w(i) * \text{Log(POIL } (-i))$$

R-Square (adjusted) = .671
 Standard Error of Estimation = .271
 Durbin-Watson = 2.16
 Estimation Period: 1965 - 1979

Where the distributed lag operator $w(i)$ takes on the value of 0.5, 0.333 and 0.169 for i equal to 0, 1 and 2.

The somewhat poor regression results for this subsector may be attributable to the purchased fuel data which have some rather sharp discontinuities. Further work in this subsector should center around explaining these discontinuities and linking the fuels more directly with the final chemical products.

4.2.6 Non-Metallic Minerals

The non-metallic minerals subsector is principally composed of concrete and cement plants, that account for approximately two thirds of total energy requirements, and a variety of smaller manufacturers of other products.

The three cement plants operating in British Columbia (a fourth, Bamberton, closed in 1981) provide finished cement to the domestic construction market and export cement and cement clinker to markets in Alaska and the northwestern U.S. In modelling this subsector, attention was focussed on factors which would affect energy consumption by these plants.

The cement industry is highly energy-intensive²⁰, and its energy requirements are tied closely to production levels. Total energy has been modelled as a function of output, measured by a weighted index of real GDP in the construction industry and exports of cement and clinker to the U.S. Efforts to incorporate the price of energy and other factors into the equation were not successful, the coefficient on the price of energy proving to be either insignificant or of the theoretically incorrect sign. The final equation, while lacking a price term, provides a relatively good fit, and the output coefficient is both significant and of a reasonable magnitude.

²⁰ Energy, Mines and Resources Canada estimated that in 1981 fuel accounted for nearly 50 percent of input costs in the Canadian portland cement industry.

$$(4.2.6.1) \quad \text{Log}(\text{OTOT}) = - 9.9928 + 0.87364 * \text{Log}(\text{XOUT})$$

(12.4) (14.9)

R-Square (adjusted) = .940
Standard Error of Estimate = .080
Durbin-Watson = 1.17
Estimation Period: 1965-1979

Attempts to develop market share equations were unsuccessful; the own and cross-price elasticities in the estimated equations were consistently found to have the incorrect sign. In the current version of the model forecasts of market shares will be set exogenously.

Some further analysis of the industry may yield fruitful results.

4.2.7 Other Manufacturing

The 'other manufacturing' subsector in British Columbia includes all those manufacturing subsectors other than the six which were modelled separately. Energy consumption in this section is not large, comprising some 2.5 percent of total industrial requirements (input petajoules) in 1979. The major energy-using industries within this category include the food and beverage, metal fabricating, and transportation industries.

Equation Specification

Total energy consumption, measured in output joules, has been modelled as a function of real GDP in the sector and of a distributed lag on the real price of energy. The estimated equation appears as:

$$\begin{aligned}
 (4.2.7.1) \quad \text{Log}(\text{OTOT}) = & - 2.3615 \\
 & (6.4) \\
 & - 0.0656 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PE}(-1)) \\
 & (0.6) \\
 & + 0.6713 * \text{Log}(\text{GDP}) \\
 & (11.3)
 \end{aligned}$$

R-Square (adjusted)	= 0.91
Standard Error of Estimate	= 0.04
Durbin - Watson	= 1.98
Estimation Period:	1965 - 1979

where the distributed lag operator ($w(i)$) takes on the values 0.5, 0.333 and 0.167 for i equal to 0, 1 and 2, respectively.

The fuel market shares have been estimated in output joules as a function of real energy prices. Coal, LPG's, and diesel, light, and heavy fuel oil were combined into a single fuel (OIL), with an appropriately defined price term.

Lagged distributions on the prices of natural gas and oil were calculated in the same manner as for the total price of energy. As in other of the industrial sectors, the electricity shares and prices performed poorly; consequently the share of electricity was exogenized and the cross-price coefficients on electricity have been set to zero.

The market share equations for natural gas and oil were estimated as:

$$\begin{aligned}
 (4.2.7.2) \quad \text{SNGS} &= (1-\text{SELC}) * (0.69059) \\
 &\quad (37.1) \\
 &- 0.15483 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PNGS}(-i)) \\
 &\quad (5.3) \\
 &+ 0.15483 * \sum_{i=0}^2 w(i) * \text{Log}(\text{POIL}(-i)) \\
 &\quad (5.3)
 \end{aligned}$$

$$\begin{aligned}
 \text{R-Square (adjusted)} &= 0.69 \\
 \text{Standard Error of Estimate} &= 0.021 \\
 \text{Durbin-Watson} &= 1.34
 \end{aligned}$$

$$\begin{aligned}
 (4.2.7.3) \quad \text{SOIL} &= (1-\text{SELC}) * (0.30941) \\
 &+ 0.15483 * \sum_{i=0}^2 w(i) * \text{Log}(\text{PNGS}(-i)) \\
 &- 0.15483 * \sum_{i=0}^2 w(i) * \text{Log}(\text{POIL}(-i))
 \end{aligned}$$

Estimation Period: 1967 - 1979

These equations fit the data reasonably well and the estimated coefficients are of the correct sign and are statistically significant.

4.3 Mining

The mining industry in British Columbia is comprised of open-pit and underground mines, producing coal, copper, lead, zinc, molybdenum, gold, silver, and other metallic and non-metallic minerals, and has been dominated since the late 1960's by large scale coal and copper open-pit operations. Both the level and mix of energy consumption in the industry are affected by the type of mining operation. Metal mines tend to be relatively more energy intensive than coal mines, and consume primarily electricity and diesel fuel oil; the mining of metallurgical coal, however, requires large volumes of natural gas for coal drying. The development of the south-east coal fields has had a substantial impact upon the pattern of energy consumption in the industry, shifting fuel usage towards natural gas from electricity and oil products. The modelling effort has attempted to incorporate the effects of changes in the composition of industry output into both the total energy and market share equations.

Total energy consumption, measured in output joules, has been modelled as a function of the real price of energy, a weighted index of mining production, and a dummy variable (DMY67) to allow for unreported HFO consumption in 1967. A lag distribution was imposed upon the real price of energy. A weighted output index was used to incorporate the variations in energy usage between types of production, and to offset scale problems, and is equal to:

$$\begin{aligned} QOUT = & (QMINCOP * 37.6757) + (QMINCOL * 0.6081) \\ & + (QMINPBZN * 3.1651) + (QMINFE * 0.9128) \end{aligned}$$

where QMINCOP, QMINPBZN, QMINFE denote copper, lead/zinc (plus molybdenum) and iron concentrate production in tonnes, and QMINCOL is coal sold and used (tonnes) and the coefficients are 1979 energy coefficients (gigajoules/tonne) for each type of production.

The estimated total energy equation appears as:

$$\begin{aligned}
 (4.3.1) \quad \text{Log}(\text{OTOT}) &= - 7.8968 \\
 &\quad (19.3) \\
 &- 0.30395 \cdot \sum_{i=0}^2 w(i) \cdot \text{Log}(\text{PE}(-i)) \\
 &\quad (1.6) \\
 &+ 1.1131 \cdot \text{Log}(\text{QOUT}) \\
 &\quad (25.8) \\
 &- 0.54161 \cdot \text{DMY67} \\
 &\quad (5.9)
 \end{aligned}$$

R-Square (adjusted)	= .984
Standard Error of Estimate	= .084
Durbin-Watson	= 1.82
Estimation Period:	1965 - 1979

where the distributed lag operator takes on the values 0.5, 0.333 and 0.167 for i equal to 0, 1 and 2, respectively.

The fuel market shares, in output joules, have been estimated as functions of real energy prices and the variable QCOL, defined as the ratio of coal production (weighted) to the index of total weighted output. Again, a dummy variable was included for 1967. Coal, LPG's, and diesel, light, and heavy fuel oils have been combined into a single energy type (OIL) with an appropriately defined price term.

The system of three equations has been estimated as:

$$(4.3.2) \quad \text{SELC} = 0.30611 \\ (6.9)$$

$$- 0.14119 * \text{Log}(\text{PELC}) + 0.14119 * \text{Log}(\text{POIL}) \\ (5.2) \quad (5.2)$$

$$- 0.1152 * \text{Log}(\text{QCOL}) + 0.17994 * \text{DMY67} \\ (5.1) \quad (5.2)$$

R-Square (adjusted)	= .736
Standard Error of Estimate	= .036
Durbin - Watson	= 1.88

$$(4.3.3) \quad \text{SOIL} = 0.3493 \\ (8.3)$$

$$+ 0.14119 * \text{Log}(\text{PELC}) - 0.14991 * \text{Log}(\text{POIL}) \\ (5.2) \quad (5.2)$$

$$+ 0.00944 * \text{Log}(\text{QCOL}) - 0.24413 * \text{DMY67} \\ (0.5) \quad (8.1)$$

R-Square (adjusted)	= .842
Standard Error of Estimate	= .030
Durbin - Watson	= 2.17

$$(4.3.4) \quad \text{SNGS} = 0.3446 + 0.10585 * \text{Log}(\text{QCOL}) \\ + 0.06469 * \text{DMY67}$$

Estimation period: 1965 - 1979

The own- and cross-price coefficients on natural gas have been restricted to zero in light of the lack of substitutability with other fuels (natural gas is used primarily for coal drying, whereas electricity and fuel oil are used to operate machinery) and the lack of acceptable empirical results.

Equations (4.3.1) through (4.3.4) fit the data well, and provide very reasonable estimates of energy price and output elasticities.

4.4 Other Industrial

The "other industrial" is the statistical difference between 1) the sum of the requirements of the manufacturing and mining subsector from the Purchased Fuels publication and reported self-generated hydroelectricity and 2) the total industrial requirements from the DESD and QRESD publications. This category consists of the fuel requirements of the forestry and construction sectors as well as the statistical differences between the surveys. This sector will be forecast exogenously.

5. TRANSPORTATION SECTOR

The transportation sector is comprised of four distinct subsectors: road, rail, marine and air. Unlike other sectors, each subsector tends to specialize in the type(s) of fuels used. For example, gasoline is used only in the road subsector whereas aviation turbo is used only in the air subsector. This specialization suggested that each subsector should be modelled separately as there is very little interfuel substitution.

The road subsector consumed approximately 74.6 percent of total energy, in input joules, in 1979 while the air, marine and rail subsectors consumed 10.7, 10.5 and 4.1 percent, respectively. In light of its importance the road subsector has been accorded the greatest attention and will be discussed first, followed by air, marine and rail.

TABLE 5-1

Energy Use in the Transportation Sector 1979¹
(petajoules)

	<u>Motor Gasoline</u>	<u>Diesel Fuel</u>	<u>Heavy Fuel</u>	<u>Aviation Turbo</u>	<u>Aviation Gas</u>	<u>Propane</u>	<u>Total</u>
Road	145.7	25.8	-	-	-	0.6	172.1
Rail	-	9.5	-	-	-	--	9.5
Marine	-	14.4	9.9	-	-	--	24.3
Air	<u>-</u>	<u>-</u>	<u>-</u>		<u>23.2</u>	<u>1.6-</u>	<u>24.8</u>
TOTAL	145.7	49.7	9.9	23.2	1.6	0.6	230.7

¹ Source: Statistics Canada QRESD.

5.1 Road

5.1.1 Overview

The road subsector is composed of the energy requirements for private passenger and commercial vehicles where private passenger vehicles are assumed to consume principally motor gasoline while commercial vehicles are assumed to consume both motor gasoline (taxis, fleet vehicles, etc.) and diesel fuel oil (principally medium and heavy trucks). The penetration of diesel fuel oil into the private passenger vehicle market is a relatively recent phenomenon. The consumption of diesel fuel by private passenger vehicles is determined exogenously, as is the consumption of other alternative fuels (CNG and propane for example).

The demand for motor gasoline by passenger vehicles is estimated using a modified version of the National Energy Board's (NEB) structural MOGAS model.² This model has the advantage of allowing the analyst to explicitly identify the impact of technological changes (for example the switch to smaller cars, or the vintaging of the vehicle stock). It also provides a framework in which to examine the potential for alternative fuels.

The model follows the vintaging of the vehicle stock through time, incorporating the number (and type) of new vehicles sold, the depreciation of existing vehicles and technological change (fuel efficiency of new vehicles). The demand for motor gasoline

² See A.S. Shalaby and R.R. Waghmare "A Model for Forecasting Passenger Car Gasoline Demand" in W.T. Ziemba, S.L. Schwartz, and E. Koenigsberg Energy Policy Modeling: United States and Canadian Experiences Volume 1.

by passenger vehicles is estimated by building up a synthetic estimate of total fuel useage by multiplying the number of vehicles of a specific age by the average kilometres driven for a vehicle of that age and multiplying this product by the fuel efficiency (litres/km) of a vehicle of that vintage. The first multiplication yields the total kilometres driven which when multiplied by the fuel efficiency renders fuel consumption. The fuel consumption is then summed across all vehicles by age and type to yield a synthetic estimate of total fuel consumption.

Relative to other parts of Canada, residents of B.C. tend to prefer smaller cars. In an attempt account for the impact this has on fuel requirements, we have tried to separate small cars from large cars.³ However, due to the paucity of a consistent historical time series for small and large vehicles, we have focused on a distinction between imported and domestic (North American) built vehicles. Most imported cars have tended to be of the small car variety while domestically produced vehicles have, until recent years, tended to be of the large car variety. We have given the imported vehicles the attribute associated with compacts and sub-compacts, while domestic cars have been assigned the attributes of compact, intermediate and large automobiles.⁴

As one might expect, building fuel requirements up from such a simple model, as described above, leads to errors in estimating actual motor gasoline requirements. To keep our estimates on track, we link the synthetic requirements, as generated by the above model, to actual "retail pump sales" as reported in the QRES.

³ The NEB's MOGAS model makes this distinction as well.

⁴ The significance of this distinction will become more apparent below in the determination of relative and average fuel efficiencies and average miles driven by vehicle class.

5.1.2 New Car Sales

New car sales have been estimated as a function of the average real price of new cars in British Columbia (PPAS), real permanent income (provided by a three year moving average, with declining weights, of real disposable income) and a dummy variable for 1970 to capture an erratic fluctuation in new car sales.

$$\begin{aligned}
 (5.1.4) \quad \text{Log}(\text{DPAS}) = & \quad 9.796 - 0.43163 * \text{Log}(\text{PPAS}) \\
 & \quad (4.7) \quad (1.5) \\
 & \quad + 0.5608 * \text{Log}(\text{YPERM}) - 0.19352 * \text{DUM70} \\
 & \quad (9.1) \quad (3.3)
 \end{aligned}$$

R-Square (adjusted) = .901
 Standard Error of Estimate = .054
 Durbin - Watson = 1.64
 Estimation Period: 1967 - 1980

The coefficient estimates are statistically significant⁵ and are consistent with consumer demand theory. New car sales were also estimated on a per household and per capita basis, however the results for the above equation appeared the most robust and displayed the most favourable properties.

The ratio of imported to domestic new car sales (DPASI and DPASD) has been modelled as a function of relative fuel efficiencies (PASEFL, PASEFS), the real price of motor gasoline (PMOG), the relative price of imported to domestic cars (PPASI/PPASD) the number of cars per household lagged one period, (KPAS(-1)/KHUS(-1)) and a dummy variable (DUM7075) to capture

⁵ The coefficient on the price variable is statistically significant at the 80 percent confidence level while the remainder are significant at the 99 percent level.

unexplained behavior in the 1970 to 1975 period. This equation was modelled in the form of a logit function where the dependent variable is the logarithm of the ratio of the probability of selecting an imported vehicle to the probability of selecting a domestic vehicle. This functional form has the property that both probabilities lie between the values of zero and unity.

$$\begin{aligned}
 (5.1.5) \text{ Log}(DPASI/DPASD) = & - 6.292 + 0.427 * \text{DUM7075} \\
 & (-4.8) \quad (5.6) \\
 & + 0.057 * ((PASEFL/PASEFS)*PMOG) \\
 & (1.7) \\
 & - 3.5542 * (PPASI/PPASD) \\
 & (-6.1) \\
 & + 5.9694 * KPAS(-1)/KHUS(-1) \\
 & (3.71)
 \end{aligned}$$

R-square (adjusted) = .840
 Standard Error of Estimate = .121
 Durbin - Watson = 1.94
 Estimation Period: 1967 - 1980

The summary statistics reported are calculated using the transformed dependent variable and fitted values. This standard error was calculated to be 2.74 percentage points when expressed in terms of the share of total vehicles represented by imported cars. The final term, the number of cars per household, is included to capture the "second car effect". This equation displays the theoretically correct signs on statistically significant variables and fits the data quite well.

Equation 5.1.5 is the only place where the price of motor gasoline appears. Efforts to include it in the demand for new cars in total were not met with much success and the likely reason for this is that gasoline expenditures are, on average, a relatively small component of total expenditures. The price of motor gasoline factors more in the decision of what type of car to buy rather than whether or not to buy a car.

5.1.3 Vehicle Stock

The development of a vehicle stock time series was beset with several difficulties.

- 1) The estimates reported by the Motor Vehicle Branch until 1974 included vehicles which were registered but not driven.
- 2) In 1974 with the inception of ICBC, it became mandatory to insure all registered vehicles and the vehicle stock was "magically" reduced.
- 3) Statistics Canada accepted the results of (1) and (2) with adjustments to the first several years of ICBC's existence. The resulting time series is somewhat erratic.

In order to produce a consistent vehicle stock time series, for British Columbia, the Ministry drew upon the experience of the NEB regarding the depreciation of motor vehicles. The Ministry experimented with the depreciation function specified by the NEB until the depreciation schedule applied to new car sales and net imports of used cars⁶ yielded vehicle stock estimates which were consistent with the reported vehicle stock data for 1978 through 1980,⁷ as reported by Statistics Canada. The "synthetic" stock estimates for the period before 1978 have been spliced to the actual vehicle stock series from 1978 onwards to form the stock series used throughout this analysis.

⁶ It was assumed that the net imports of cars have the same age distribution as British Columbia as a whole.

⁷ The final estimates suggested a half life of 12.8 years and a maximum life of 20 years. The half life may be interpreted as the number of years after which 50 percent of new cars sold in a year are expected to still be on the road.

5.1.4 Kilometres Driven

The average number of kilometers driven (AVGKM) has been defined as a function of the age of the vehicle. While economic theory would suggest that average miles driven depends as well upon the income of consumers, the cost of driving (relative to other transport modes) and other factors, there appears to be insufficient data to empirically test these hypotheses.

The following equations were developed for different vehicle types by Environment Canada (and reported by the NEB⁸) on the basis of cross-section survey data.

Subcompact:

$$\begin{aligned} \text{AVGMILES} &= 12,036 - 723 * (\text{age of car}) \\ R^2 &= 0.77 \end{aligned}$$

Compact:

$$\begin{aligned} \text{AVGMILES} &= 10,033 - 445 * (\text{age of car}) \\ R^2 &= 0.65 \end{aligned}$$

Intermediate:

$$\begin{aligned} \text{AVGMILES} &= 11,434 - 484 * (\text{age of car}) \\ R^2 &= 0.57 \end{aligned}$$

Standard:

$$\begin{aligned} \text{AVGMILES} &= 12,829 - 610 * (\text{age of car}) \\ R^2 &= 0.80 \end{aligned}$$

⁸ Shalaby and R.R. Waghmare, op. cit., p. 124

For our definition of imported cars, we adopted a simple average of the coefficient on the age of car variable for the compact and sub-compact equations. Similarly for domestic cars, we adopted a simple average of the compact, intermediate and standard mileage equations to reflect a predominance of smaller North American built cars in British Columbia. The constant terms for the small (imported) and large (domestic) car equations were estimated such that the equations, when substituted with the average age of the entire vehicle stock, yielded, as a result, average miles driven in B.C., as reported in the Statistics Canada publication "Passenger Car Fuel Consumption Survey." Imported cars, are assumed to be driven about 1000 miles a year less than the average, as reported by the NEB for small and large cars.

The equations for average annual kilometres travelled are:

(5.1.6) Imported Cars:

$$AVGKMI = (12321.4 - 584 * CARAGE) * 1.609$$

(5.1.7) Domestic Cars:

$$AVGKMD = (12819.8 - 513 * CARAGE) * 1.609$$

where CARAGE is 7.06 years - the average age of the vehicle stock derived from the calculation of the vehicle stock.

Average fuel usage (L/100 Km) for both large and small cars has been taken from the NEB and the U.S. Department of Energy.⁹ A degradation factor, to incorporate the difference between

⁹ Howard Walton et al. Fact Sheet: Forecasted Automobile Gasoline Consumption. U.S. Department of Energy. DOE/EIA-0102/1.

performance under test and actual conditions, is then applied. We used the breakdown of fuel efficiencies between urban and highway driving for the subcompact, compact, intermediate and standard categories, as reported in Shalaby and Waghmare, and weighted them in the same manner as for average annual mileage, as discussed above, to arrive at our domestic/imported car fuel usages. Estimates of the proportion of urban travel in British Columbia by Environment Canada were also used to aggregate city and highway fuel usage.¹⁰

5.1.5 Total Fuel Motor Gasoline Requirements

The estimated stocks, average annual kilometers travelled and the average fuel efficiencies for each vehicle are multiplied and aggregated to obtain a synthetic estimate of total motor gasoline requirements by private passenger vehicles. Thus the demand for retail gasoline sales in year T is:

$$(5.1.8) \text{DMOGCAR}^T = \sum_{j=0}^{-20} \text{KPASIT}_j^T \cdot \text{AVGKML}(j) \cdot \text{PASEFI}_{-j} \\ + \sum_{j=0}^{-20} \text{KPASDT}_j^T \cdot \text{AVGKMS}(j) \cdot \text{PASEFD}_{-j}$$

DMOGCAR is then compared to actual "retail pump sales" as reported by Statistics Canada in QRESD for the years 1978 to 1980. The average proportional difference between the actual and synthetic requirements are held constant over the forecast period. At some future date, we may examine introducing a bridge equation between these two series.

¹⁰ Environment Canada estimated that 67 percent of small car driving time was in urban areas and 68 percent for large cars for British Columbia. By way of comparison the figures for Ontario are 60.0 and 60.5 respectively.

In the current version of the model, motor gasoline requirements by commercial and other vehicles (DMOGOTH) are estimated exogenously. Total road motor gasoline requirements are then determined by adding the requirements from private passenger vehicles (DMOGCAR) and other uses (DMOGOTH).

5.1.6 Diesel Fuel Requirements

Diesel fuel oil in the road sector is historically assumed to be consumed by commercial vehicles. Consumption has been modelled as a function of total GDP, the price of road diesel to off-road diesel,¹¹ and a lagged dependent variable.

$$\begin{aligned}
 (5.1.9) \quad \text{Log(DDFOROD)} &= - 8.4733 + 1.0276 * \text{Log(XGDPTOT)} \\
 &\quad (3.3) \quad (3.5) \\
 &\quad - 1.3233 * \text{Log(PDFOROD/PDFONRD)} \\
 &\quad (1.9) \\
 &\quad + 0.38856 * \text{Log(DDFOROD(-1))} \\
 &\quad (2.0)
 \end{aligned}$$

R-square (adjusted)	= .975
Standard Error of Estimate	= .125
Durbin-Watson	= 1.88
Estimation Period:	1961 - 1980

This equation exhibits a rather large long run elasticity of diesel fuel oil consumption relative to economic activity (1.68) and will be monitored closely.

¹¹ This is to represent the relative costs facing the consumer when making a choice between road or rail transport.

5.2 Air

The air transport subsector consumes aviation gasoline and aviation turbo fuel. Since the aviation gasoline component is relatively stable and is not substitutable for aviation turbo fuel, it will be forecast exogenously. The demand for aviation turbo (DAVTAIR), in output joules, is modelled as a function of the number of passengers (NPASAIR) and the price of aviation fuel (PAVT) relative to the consumer price index (PCPI).

$$(5.2.1) \quad \text{Log(DAVTAIR)} = \begin{matrix} 0.58175 \\ (2.7) \end{matrix} + \begin{matrix} 1.1094 \\ (30.7) \end{matrix} * \text{Log(NPASAIR)} \\ - \begin{matrix} 0.38045 \\ (2.85) \end{matrix} * \text{Log(PAVT/PCPI)}$$

R-square (adjusted) = .988
 Standard Error of Estimate = .069
 Durbin - Watson = 1.89
 Estimation Period: 1963 - 1979

The number of passengers is in turn modelled as a function of population (NPOP), real per capita disposable income and the price of airline travel.

$$(5.2.2) \quad \text{NPASAIR/NPOP} = \begin{matrix} -0.00026179 \\ (0.5) \end{matrix} + \begin{matrix} 0.0010156 \\ (30.1) \end{matrix} * \text{YNDPI/(PCPI*NPOP)} \\ - \begin{matrix} 0.0015781 \\ (2.5) \end{matrix} * \text{PPASAIR/PCPI}$$

R-square (adjusted) = .984
 Coefficient of Variation¹² = 5.4 percent
 Durbin - Watson = 0.86
 Estimation Period: 1963 - 1979

Finally, the price of airline travel has been modelled as a log linear function of the price of aviation turbo fuel and consumer price index.

¹² defined as the standard error of the estimate divided by the mean of the dependent variable and expressed as a percent.

$$\begin{aligned}
 (5.2.3) \quad \text{Log(PPASAIR)} &= - 0.32418 + 0.15692 * \text{Log(PAVT)} \\
 &\quad (3.7) \quad (3.3) \\
 &\quad + 0.84308 * \text{Log(PCPI)} \\
 &\quad (17.5)
 \end{aligned}$$

R-square (adjusted) = .990
 Standard Error of Estimate = .036
 Durbin-Watson = 1.50
 Estimation Period: 1962 - 1979

This system of equations seems to fit reasonably well.

5.3 Marine

Separate equations for diesel and heavy fuel oil requirements have been estimated as heavy fuel oil, for the most part, is destined for the bunkering of deep sea vessels while diesel fuel oil is consumed principally in coastal operations including the B.C. ferry fleet. The demand for each fuel will depend on different explanatory variables.

Heavy fuel oil consumption has been modelled as a function of export shipping activity and the price of heavy fuel oil prices in B.C. relative to world oil prices. The total weight of exports of grain, pulp and lumber from B.C. (SHIPRAL) has been taken as an index for international shipping activity in B.C. Ships often have the ability to either double-bunker (carry enough fuel for a return trip) or bunker in neighbouring U.S. ports should the price of B.C. heavy fuel oil be excessively large. As the world heavy fuel oil price has generally tracked the world crude oil price, the ratio of the B.C. heavy fuel oil price to the international crude price (Saudi Arabian light) serves as a proxy for the competitiveness of B.C. heavy fuel oil in world markets.

A dummy variable for 1980 has been included in the analysis due to a very large unexplained deviation in that year.¹³

$$(5.3.1) \quad \text{Log}(\text{DHFOMAR}/\text{SHIPMAR}) = - 3.6234 - 0.6260 * \text{DUM 6979} \\ (8.1) \quad (3.4) \\ - 0.5971 * \text{Log}(\text{PHFOMAR}/\text{POILWRD}) \\ (3.4)$$

R-Square (adjusted) = .790
 Standard Error of Estimate = .157
 Durbin-Watson = 1.74
 Estimation Period: 1969 - 1980

Diesel fuel oil requirements are generally associated with domestic coastal shipping activity variables for coastal lumber production (QLUMGST), the major industrial activity requiring transport from the Mainland, and a lagged dependent variable. A dummy variable was included to capture an unexplained structural shift in the data after 1977. Attempts to introduce a price term into the equation were not met with success.

¹³ The volume of heavy fuel oil consumed in the marine market reported by Statistics Canada has been very volatile over recent years, rising from 9.9 petajoules in 1979 to 19.5 petajoules in 1980 and 30.4 petajoules in 1981.

$$\begin{aligned}
 (5.3.2) \quad \text{Log(DDFCMAR)} &= - \begin{matrix} 7.8079 \\ (3.7) \end{matrix} - \begin{matrix} 0.2277 \\ (2.0) \end{matrix} * \text{DUM6777} \\
 &+ \begin{matrix} 0.4937 \\ (3.0) \end{matrix} * \text{Log(QLUMCST)} \\
 &+ \begin{matrix} 0.6867 \\ (2.0) \end{matrix} * \text{Log(NPOPV)} \\
 &+ \begin{matrix} 0.3715 \\ (1.6) \end{matrix} * \text{Log(DDFCMAR(-1))}
 \end{aligned}$$

R-square (adjusted) = .887
 Standard Error of Estimate = .089
 Estimation Period: 1967 - 1980

Although there is a substantial amount of unexplained variation in the two equations, the estimated coefficients are generally reasonable and statistically significant and the resulting forecasts provide reasonable dynamic properties.

5.4 Rail

Diesel fuel oil is consumed in the rail sector principally for providing locomotive power. As trains entering the province may consume fuel purchased outside the province, there is some difficulty in linking fuel requirements as reported in the Statistics Canada publication QRESD with economic activity.

Diesel fuel oil requirements have been modelled as a function of the major commodities carried by rail, the real price of energy and a lagged dependent variable. The three major commodities shipped by rail (Interior lumber, coal and grain) have been combined into a single composite index (SHIPRAL).

This equation was estimated in the form:

$$\begin{aligned}
 (5.4.1) \quad \text{Log(DDFORAL)} &= - 0.2024 + 0.4632 * \text{Log(DDFORAL(-1))} \\
 &\quad (0.9) \quad (3.3) \\
 &\quad + 0.3482 * \text{Log(SHIPRAL)} \\
 &\quad (3.6) \\
 &\quad - 0.4050 * \text{Log(PDFONRD/PCPI)} \\
 &\quad (2.7)
 \end{aligned}$$

R-squared (adjusted) = .910
 Standard Error of Estimation = .087
 Durbin - Watson = 1.67
 Estimation Period: 1961 - 1980

The equation is reasonably well specified with correct and significant a priori signs on the coefficients. The equation has a short run price elasticity of .4 and a long run price elasticity of approximately .75.

6. NON ENERGY DEMAND

6.1 Lubes and Greases

Lubricating oils and greases have been modelled as a function of GDP in industries which are particularly motive machinery intensive (construction, mining and transportation, communication and storage) and a lagged dependent variable.

$$\begin{aligned} (6.1.1) \quad \text{Log(DLGR)} = & - 2.0248 + 0.3660 * \text{Log(GDP)} \\ & (2.5) \quad (2.7) \\ & + 0.413 * \text{Log(DLGR(-1))} \\ & (2.2) \end{aligned}$$

R-Square (adjusted) = .979
Standard Error of Estimate = .036
Durbin's H Statistic = 3.04
Estimation Period: 1961 - 1979

The equation fits reasonably well and has a long run elasticity of about 0.62 on output.

6.2 Asphalt

The demand for asphalt has been modelled as a function of aggregate GDP and the lagged dependent variable in the form:

$$\begin{aligned} (6.2.1) \quad \text{Log(DASP)} = & - 3.5282 + 0.5285 * \text{Log(GDP)} \\ & (1.6) \quad (2.3) \\ & + 0.4600 * \text{Log(DASP(-1))} \\ & (2.1) \end{aligned}$$

R-Square (adjusted) = .900
Standard Error of Estimate = .104
Durbin's H Statistic = 2.08
Estimate Period: 1961 - 1979

6.3 Petroleum Coke

The demand for petroleum coke (excluding that portion consumed within petroleum refineries) will be forecast exogenously in the current version of the model.

6.4 Petrochemicals

The natural gas (feedstock, compressor fuel, losses and fuel) and electricity requirements for the production of petrochemicals and liquified natural gas are forecast exogenously based on committed and forecasted energy projects.

7. CONVERSION FROM SECONDARY TO PRIMARY REQUIREMENTS

Once secondary energy requirements have been modelled, as discussed in sections (2) through (6) above, the associated requirements of the energy supply industries are calculated and added to obtain the total primary energy demand. This calculation is undertaken for each of electricity, natural gas and oil.

1) Electricity

The consumption of the electricity supply industry consists of the natural gas and refined petroleum products consumed in the generation of electricity by utilities and of electricity losses in the transmission and transformation of electricity. The fossil fuels consumed are forecast exogenously in the current version of the model and the transmission losses are a function of total electricity sales.

2) Natural Gas

Primary natural gas requirements are here defined as natural gas consumed downstream of the natural gas plant. The difference between domestic supplies and final demand consists of natural gas exports, net imports, natural gas consumed in generating electricity by utilities, transmission and distribution losses. Natural gas exports/imports and consumption in electricity generation are forecast exogenously. The determination of distribution and transmission losses draw heavily from information garnered during the Govier Natural Gas Surplus Inquiry.¹ Distribution

¹ See George W. Govier, Commissioner Inquiry on British Columbia's Requirements, Supply and Surplus of Natural Gas and Natural Gas Liquids, Technical Report, May 1982.

losses are modelled as a function of utility sales² and transmission losses are modelled as a function of total throughput on the Westcoast system (including domestic sales, exports under GL-41 from Huntingdon and distribution losses).

3) Oil

The modelling of the energy requirements for petroleum refineries is discussed under section 4.2.4 above. Total domestic refined petroleum production may be added to still gas, non-energy products and other miscellaneous requirements to obtain the energy in the form of crude oil required by British Columbia refineries. Net imports/exports are set such that domestic demands for refined petroleum products are met without exceeding refinery capacity.

² At this point, the model crudely produces utility service area forecasts for producing estimates of distribution losses on the basis of the 1981 sales distribution and the growth of natural gas requirements by sector. This mechanism will be over-written if the model is fully regionalized.

8. REGIONALIZATION IN THE MODEL

The major orientation of the present model is to forecast the provincial demand for energy. By and large, total province equations have been developed. A significant exception is for the residential and commercial sectors where on a priori grounds, separate estimates have been developed for the Mainland (M) and Vancouver Island (V). As well, a regional approach has been used for pulp and paper.

In general, further regionalization is incorporated into the model by applying exogenous splitting ratios to the provincial aggregates. At present, the simulator provides the user with the option of specifying a region number (1,...,7), the number of regional variables to be printed for that region, and the variable number of the desired endogenous variables. The same procedure can be applied to each region in any order.

The seven regions and their associated number are as follows:

- Region 1: Lower mainland (L)
- Region 2: Vancouver Island (V)
- Region 3: Pacific Northern Gas (P)
- Region 4: Inland Natural Gas - North (N)
- Region 5: Inland Natural Gas - South (S)
- Region 6: Columbia Natural Gas (C)
- Region 7: Rest of Province - North (Z)

9. MODEL TESTING: DYNAMIC PROPERTIES

In order to assess the dynamic properties of the model, a number of tests were conducted. First, the model was simulated over the period 1978-2000, using interim forecasts of exogenous variables, to generate a base case, or control solution. A series of 'shock' solutions were then generated in which each of the major fuel prices (natural gas, electricity, oil products) were separately increased by 20% for the 1983-2000 period. The change in the values of the endogenous variables (final demand for natural gas, purchased electricity, oil and total energy in input joules) in the year 2000 were then calculated as a percentage of the control solution values. A final shock experiment was conducted in which all three prices were simultaneously increased by 20% in 1983.

The resultant own- and cross-price elasticities of demand (defined as the percentage change in quantity divided by the percentage change in price) for purchased electricity, natural gas, oil and total energy, are given in Table 9-1. The transport sector has been identified separately within both oil and total energy in order to net out the effect on the elasticities of the sector's large size and lack of responsiveness to energy price changes.

The negative cross-price elasticities in Table 9-1 reflect the fact that for example while an increase in the price of electricity leads to an increase in the market share of natural gas, the consumption of natural gas decreases since total energy consumption has also been reduced.¹

¹ This is analogous, in economic theory, to having the income effect swamp the cross substitution effect. The own-price elasticity is unambiguously negative.

Table 9-1
Implied Long Run Price Elasticities

Consumption	Energy Prices			
	Electricity	Natural Gas	Oil	Total
Electricity (Purchased)	-.428	-.045	+.206	-.287
Natural Gas	-.071	-.263	+.121	-.219
Oil	+.119	+.067	-.311	-.118
- Transport	0	0	-.115	-.115
- Excluding Tr.	+.449	+.251	-.849	-.126
Total	-.037	-.051	-.061	-.152
- Excluding Tr.	-.052	-.072	-.040	-.166
Purchased	-.044	-.061	-.074	-.182
- Excluding Tr.	-.069	-.094	-.051	-.220

It is important to emphasize that the estimates in Table 9-1 are for exposition only since magnitude of the parameters are in part dependent upon the assumptions of economic activity and prices which generate the base case. The signs and magnitudes of the own-and cross-price elasticities seem very reasonable.

The model is essentially recursive and possesses very stable dynamic properties.

10. EXOGENOUS VARIABLES

Historical values for each exogeneous variable are contained in the data base and simulation files for the model.

Forecasts of the exogenous variables are brought into the model in three different ways:

- 1) The time series may be embedded in the data base and simulation files.
- 2) The values may be generated within the model in one of the CONS (mnemonic for constants) routines.
- 3) The simulator may read in these values directly from a CMS file.

Currently, economic activity variables are set within the CONS routines and energy prices are set both within the model and read from outside CMS files. The latter mechanism is invaluable as it provides a mechanism for linking exogenous APL and other models to the energy demand model.

11. USES OF THE MODEL

11.1 Overview

The energy demand model is a straightforward, flexible and sophisticated econometric model which can serve the purposes of forecasting, planning and policy analysis. The model has extensive sectoral coverage, the specified equations are generally well-grounded in economic theory, the statistics of most estimated equations are quite reasonable, and the model is robust. The method of model construction - from data collection to model simulation - is straightforward and it is easy to modify data, individual equations or even whole sectors. The model's ability to adequately explain historical energy consumption provides a sound basis upon which to build forecasts and analyze policy options.

11.2 Forecasting

One major purpose of the energy demand model is to aid in the generation of a forecast of the endogenous variables, mostly energy fuel demands by sector.

11.3 Policy Analysis

A second major purpose of the B.C. Energy Demand Model is policy analysis. Energy prices and various other variables are embedded in the model as exogenous variables which are under the control of the government. The model can be used to analyse the impacts of changing these policy levers.

The simulator package that controls the model will allow the user to examine the differences between a 'control' solution and a policy 'shock' solution in 'shock minus control' format or in ratio 'shock minus control as a percent of control' format. Thus, comparison of various policy scenarios is readily facilitated.

11.4 Sensitivity Analysis

As well as being useful for policy analysis and forecasting, the model can be used for sensitivity analysis. Sensitivity analysis involves shocking an important exogenous variable or equation structure and observing the impact on the endogenous variables. For example, one might be interested in the consequences for energy fuel demand due to different assumptions about world oil prices, economic growth in B.C., or improvements in technical efficiency in the road transportation sector.

12. FURTHER WORK

As noted, the above summarizes a first cut effort to develop an Energy Demand Forecasting and Planning Model for British Columbia. The goal was to develop theoretically sound and empirically robust econometric equations which would capture historical energy demand behavior in B.C. with sufficient detail on sectors and energy types to permit reasonably detailed policy analysis. Further, the system of equations was to be embedded in an efficient and flexible computer software package, supported by a comprehensive and internally consistent data base.

In general, the effort was quite successful. In most areas, quite reasonable (i.e., theoretically and empirically sound) equations have been developed to represent energy demands. The successful incorporation of energy prices into most equations stands out in this regard. Further, significant progress has been made in the data area, and we have the model (i.e. system of equations) up and running on what we judge to be quite a good software package (i.e., simulator).

Notwithstanding the above, further work is desirable in a number of areas. In several sectors, it is suspected that further research will yield somewhat more robust equations. As well, some areas presently treated exogenously deserve further examination. More generally, expansion of the model would facilitate policy analysis. Two possibilities are the further development of retail energy price determination modules and the linking of the model with a (yet to be developed) long term model of the B.C. economy. Finally, more work is desirable in the area of regionalization.

13. REFERENCES

- [1] Almon, S., 'The Distributed Lag Between Capital Appropriations and Expenditures', Econometrica, Vol. 30, pp. 178-196, 1965.
- [2] Berndt, E., M. Fuss, and L. Wavermann, Empirical Analysis of Dynamic Adjustment Models of the Demand for Energy in U.S. Manufacturing Industries 1947-74, Research Report, Electric Power Research Institute, Palo Alto, 1980.
- [3] Cox, A.J. and J.F. Helliwell, Economic Modelling of Energy Supply from Burning Wood Wastes at British Columbia Pulp and Paper Mills, Resources Paper No. 21, University of British Columbia, 1978.
- [4] Denny, M., M. Fuss and L. Wavermann, The Substitution Possibilities for Energy: Evidence from U.S. and Canadian Manufacturing Industries, Toronto Institute for Policy Analysis, July 1980.
- [5] Energy, Mines and Resources, Energy Demand Projections: A Total Energy Approach, Report ER-77-4, Ottawa, 1977.
- [6] Environment Canada, Canadian Automobile Driver Survey, Economic and Technical Review Report, EPS 3-AP-73-10.
- [7] Helliwell, J.F., and M. Margolick, Some Hard Economics of Soft Energy: Optimal Electricity Generation in Pulp and Paper Mills with Seasonal Steam Requirements, Resources Paper No. 56, University of British Columbia, 1980.
- [8] _____, and A.J. Cox, Wood Wastes as an Energy Source for the B.C. Pulp and Paper Industry: Economic Implications and Institutional Barriers, Resources Paper No. 19, July 1978.

- [9] Intriligator, M.D., Econometric Models, Techniques and Applications, Prentice-Hall, 1978.
- [10] Johnston, J., Econometric Methods, 2nd Edition, McGraw Hill, 1972.
- [11] Margolick, M., A.H. Hansson, and J.F. Helliwell, Competing Energy Uses for Wood Wastes in British Columbia, Resources Paper No. 65, University of British Columbia, July 1981.
- [12] _____, and J.F. Helliwell, Electricity Generation From Wood Wastes in British Columbia, Resources Paper No. 69, University of British Columbia, July 1981.
- [13] McRae, R.W., 'Regional Demand for Energy by Canadian manufacturing Industries', International Journal of Energy Systems, 1981.
- [14] Ministry of Industry and Small Business Development, British Columbia Economic Accounts 1961-1980: Experimental, May 1982.
- [15] Ministry of Energy, Mines and Petroleum Resources, Energy Supply and Requirements Forecast 1980-1995, April 1981.
- [16] Preece, R.A., L.B. Harsanyi and H.M. Webster, The Energy Demand Forecasting System of the National Energy Board, in W.T. Ziemba et. al. Energy Policy Modelling: United States and Canadian Experiences, Vol.-1, Martinus Nijhoff Publishing, 1980.
- [17] Pindyk, R.S. and D.L. Rubinfeld, Econometric Models and Economic Forecasts, McGraw-Hill, 1976.

- [18] Sahi, R., and R. Erdman, 'A Policy Model of Canadian Interfuel Substitution Demands' in W.T. Ziemba et. al., Energy Policy Modelling: United States and Canadian Experiences, Vol.-1, Martinus Nijhoff Publishing, 1980.

- [19] Shalaby, A.S., and R.R. Waghmare, 'A Model for Forecasting Passenger Car Gasoline Demand', in W.T. Ziemba et. al., Energy Policy Modelling: United States and Canadian Experiences, Vol.-1, Martinus Nijhoff Publishing, 1980.

- [20] Shiller, R.J., 'Rational Expectations and the Dynamic Structure of Macroeconomic Models', Journal of Monetary Economics, pp. 1-44, January 1978.

- [21] Statistics Canada, Consumption of Purchased Fuel and Electricity, Catalogue No. 57-506 and 57-208.

- [22] _____, Detailed Energy Supply and Demand in Canada, Catalogue No. 57-207.

- [23] _____, 'Passenger Car Fuel Consumption Survey', July 1981.

- [24] _____, Quarterly Report on Energy Supply - Demand in Canada, Catalogue No. 57-003.

- [25] Theil, Henri, Principles of Econometrics, John Wiley and Sons, 1971.

- [26] Walton, H. et. al., Fact Sheet: Forecasted Automobile Gasoline Consumption, U.S. Department of Energy DOE/EIA-0102/1.

- [27] White, K.J., 'A General Computer Program for Econometric Methods - SHAZAM', Version 3.1.1, Rice University, 1980.

